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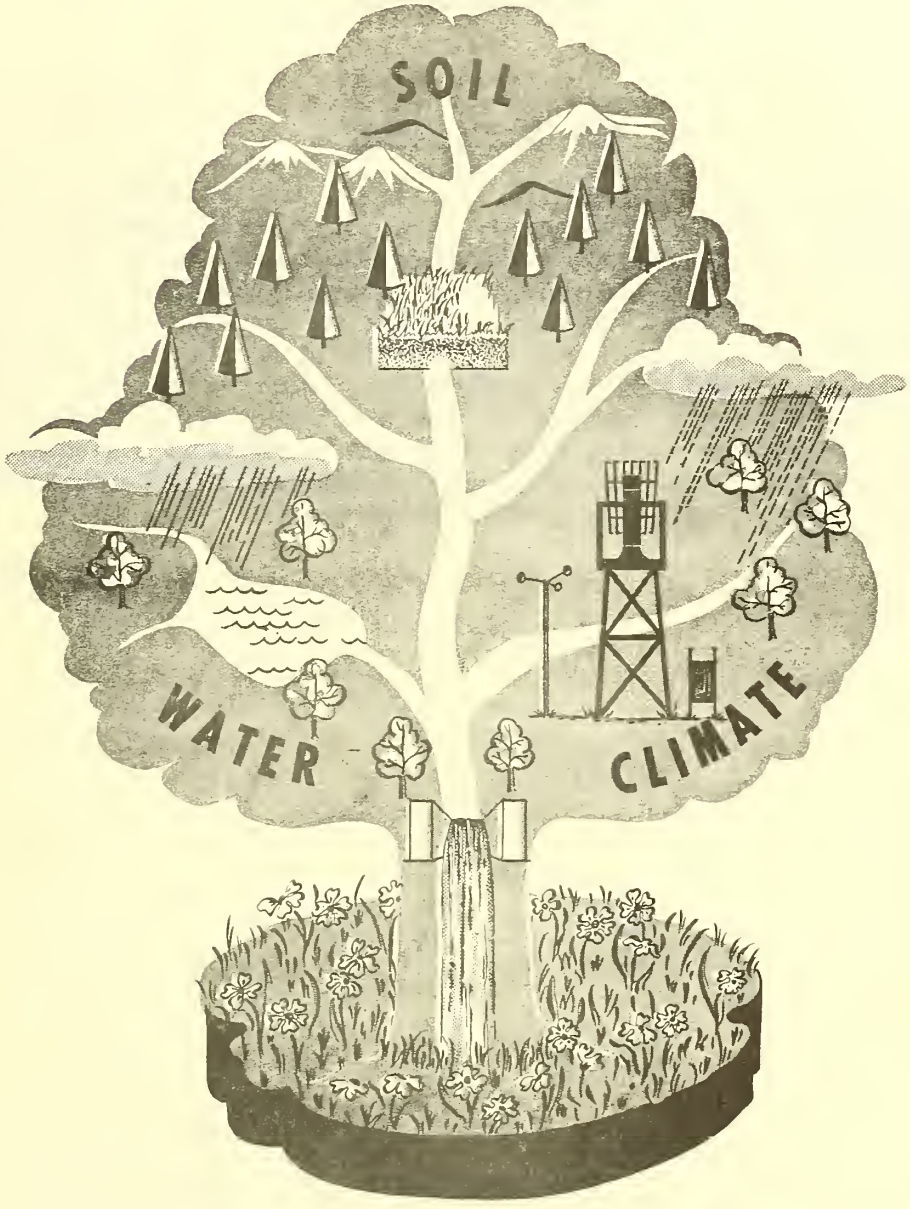
DIVISION OF
WATERSHED MANAGEMENT RESEARCH

Semiannual Report



U. S. DEPARTMENT OF AGRICULTURE - FOREST SERVICE

OCTOBER 1962 MAR 1963

USE OF THIS REPORT

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Division of Watershed Management and Recreation Research
October 1962 - March 1963

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Division of Watershed Management Research

CENTRAL STATES FOREST EXPERIMENT STATION

October 1962 - March 1963

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Intermountain Forest and Range Experiment Station
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SEMIANNUAL REPORT
Division of Watershed Management and Recreation Research
October 1962 - March 1963

Washington Office

More Reorganization

In the last report we told you of the reorganization of the W.O. Division to include recreation as well as watershed management research. This has been taken one step further and we are now organized into two branches, with Clark Holscher as Chief of the Branch of Forest Soil and Water Research and Walt Hopkins as Chief of the Branch of Forest Recreation Research. The position of Assistant Director of the Division, previously occupied by Holscher, has been abolished.

Jim Smith Turns to Snow

We don't know whether to call it accretion, sublimation, interception, infiltration or anticipated base flow, but anyway, the Pacific Southwest Station has put the finger on Jim Smith and said, "We want you." Jim is being promoted to project leader of snow research in California, one of several jobs Henry Anderson has been holding down. Henry will now be able to devote full time to leadership and research on the water sources hydrology project at PSW.

As most of you know, the position occupied by Jim in the W.O. is weighted heavily toward training. Jim was born and raised in Georgia and has lived most of his life in the South. Although he has seen a good many parts of the U. S. while working in the W.O., it seems that the one thing really lacking in his experience is snow. So this assignment to the snow project is going to benefit everyone (except the W.O.; we'll miss him). One thing we're sure of--Jim will dig hard to keep from being snowed under. Perhaps, if he does well, he will make it to Alaska some day.

Recreation Research Will Try a Semiannual Report

Walt Hopkins has always been a strong supporter of the Semiannual Report. At a recent meeting of his recreation research people in Berkeley, he presented this as a useful tool for communication between scientists, and the group decided to try a Semiannual Report for Recreation Research for one year. After that time a more permanent decision will be made. We urge you to lend the recreation research folks a hand, by making copies of your reports available to them, by describing the types of materials you include and the usefulness you find in the report.

SEMIANNUAL REPORT

Division of Watershed Management Research
Central States Forest Experiment Station

October 1962 - March 1963

I. Forest Restoration and Watershed Management On Strip Mine Lands

by Robert F. May

A. Personnel

A research forester, William T. Plass, joined the project in November to assist with revegetation studies. He transferred from the Division of Forest Management at Carbondale, Illinois and his past experience will be utilized in studies designed to promote growth of trees and shrubs on strip mine spoils. Cooperators, in studies initiated or approved for early implementation, include the Kentucky Reclamation Association, Tennessee Valley Authority, Kentucky Department of Conservation, and Berea College.

B. Studies

Swell and Angle of Repose of Freshly Formed Spoil Banks from Rock-Soil overburden when excavated over coal seams in Harlan, Kentucky, area is approximately 75 percent complete.

Strip Mining Effects upon Chemical Characteristics of Water in the Forester's Creek Watershed, Harlan County, Kentucky is continuing. This is an exploratory study to measure possible increase in dissolved solids as the result of strip mining. Results to date indicate there has been practically no change in water quality.

Evaluation of Some Plant Species for Late Summer and Fall Seeding to Give Quick Cover on Strip Mine Spoil showed promise after the mid-December count. Cover ranged from 20 to 60% depending upon seeding dates which were semi-monthly from August 1 to October 15. However, the severe winter which aggravated frost heave and also caused land slides practically obliterated all study plots.

A Fertility Evaluation of Coal Strip Mine Spoil From Certain Stratigraphic Horizons in Eastern Kentucky study was begun in the Berea College greenhouse during January, 1963. As expected from previous reports, growth varied considerably from spoil to spoil. Also, preliminary observations show a considerable variation in growth from the same spoil. It was also necessary to mulch the pots to induce sprouting because of severe crusting of the spoil. This suggests further study is required to determine the cause of severe crusting. In pots where growth failed or was poor an accumulation of salts on the surface was evident.

Studies planned to get underway during the next 6 months include:

1. The Influence of Established Grasses and Legumes on the Survival and Growth of Trees Planted on Spoils in Eastern Kentucky Coal Fields.

2. Revegetating Long Outslopes To Control Sheet and Rill Erosion By Seeding Grasses and Legumes Between Contour Plantings of Black Locust and European Alder.

3. Identification and Occurrence of Pyritic Material in Overburden Stripped For Coal in Eastern Kentucky.

4. Evaluation of Some Plant Species for Spring, Summer, and Fall Seeding To Give Quick Cover on Strip Mine Spoil.

5. Changes in Chemical Characteristics of Coal Strip Mine Spoil Surface with Time.

We have continued participation in the Beaver Creek administrative study with seven federal and four state agencies as during the past year. Information gained from this study has provided excellent planning factor data for studies designed to probe deeper into the strip mined area problems.

C. Straight Creek Experiment Area

A prospectus for a cooperative pilot study of The Impact of Rim Type Strip Mining Upon Watershed Values has been prepared for review by the proposed cooperators which include the Kentucky Reclamation Association, Tennessee Valley Authority, Kentucky Department of Conservation, and private coal mine operators. This 20 square mile watershed in Harlan County, Kentucky, lies north and adjacent to Pine Mountain and offers an excellent opportunity for the pilot study because no previous deep mining has been done in the area to be strip mined. Two operable seams of coal can be mined along more than 20 miles of crop line. This should permit ample pre-treatment calibration for 9 unit and 4 multiple area sampling stations. Implementation of the pilot study will necessarily depend upon the extent of cooperation and the availability of funds.

D. Cooperative Aid Studies

The strip mined area restoration project is involved in two cooperative aid studies underway with land-grant universities in the Midwest. They are:

Ohio State University - Develop methods of determining and establish the factors which influence the structural stability of the overburden of the Lower Kittanning Coal Seam in the Ohio Valley.

Purdue University, Indiana - Determine cover type utilization by cottontail rabbit in Southern Indiana coal stripped lands.

II. Nuclear Equipment Evaluation — by Richard B. Marston

A. Duration and number of observations for measuring soil moisture with a subsurface neutron meter. (Revision of our April-September 1962 report.)

Count rate error formulas discussed in our previous semiannual report have been revised so as to incorporate standard deviation approximations from the Poisson distribution shown by Jarrett.[1/] His count-rate error for any number of radioactive counts at one point is given by the equation:

$$E = K \sqrt{\text{i.p.m.}/(t)(m)}$$

where i.p.m. is the count-rate in impulses per minute; E is the error or one-half confidence interval, here expressed in i.p.m.; K is the normal deviate obtainable from tables for a selected level of significance; t is the length of the observation time; and m is the number of observations at one point.

Error may be determined as a proportion of i.p.m. by the equation

$$E^2_{(prop)} = K^2/(t)(m)(\text{i.p.m.})$$

From this equation it is clear that with K, t, and m held constant, the proportional error increases as i.p.m. decreases. Therefore, to hold proportional error constant, the quantity (t m) must increase as i.p.m. decreases. The quantity (t m) becomes relatively large for dry soils because the i.p.m. from them is small.

Merriam[2/], however, points out that the impulse rate *per se* is not really the response we are after. Instead, we want moisture in percent by volume (Pv). This final quantity is predicted from the impulse rate by the use of a calibration curve. Merriam's development of equations involving the error in Pv shows percent error to be reduced for drier soils when K, t, and m are held constant. Furthermore, when the error in Pv is held constant, the quantity (t m) will be small relative to what it will be for a moist soil.

1/ Jarrett, Alan A. 1956. Statistical methods used in the measurement of radioactivity--with some useful graphs and nomographs. U.S. Atomic Energy Comm. AECU-262, 43 pp. illus.

2/ Merriam, Robert A. 1962. Useful statistical guides and graphs for neutron probe soil moisture sampling. U.S. Dept. Agric., For. Ser., Int. For. & Range Expt. Sta., Research Paper No. 62, 9 pp.

According to Merriam's development, the required duration for a nuclear meter observation is predictable when the following are known:

1. Slope of the calibration curve,
2. Allowable error,
3. Probability level,
4. Soil moisture content, percent by volume.

B. Surface density probe

In your April 1962-September 1962 report please change this heading to:

Subsurface density probe.

C. Readings in air, in soil, and over water, made with a surface moisture probe.

Recently we have obtained some additional information on the volume of material that is sampled by our nuclear surface moisture meter. One condition we studied was the relation of impulses per minute (i.p.m.) to the thickness of layers of water in a 55-gallon steel drum. Our results showed that the background i.p.m. was low, that the i.p.m. increased rapidly as the water layer increased to 3-inches thick, and that the i.p.m. leveled off when the water layer was 5-inches or more thick (Fig. 1A). Another feature of our study was to determine the relation of i.p.m. to the suspension distance between the meter and the surface of the bulk shielding facility pool at Ohio State University's nuclear reactor. The results here were somewhat the reverse of those from the different layers of water. That is, the initial reading on the surface of 9-feet of water in the 16-foot deep pool was high, approximately the same as for a 5-inch layer of water, the impulse rate dropped rapidly as the suspension distance increased to about 3 inches, but beyond about 3 inches the impulse rate decreased more slowly and the decrease was extremely slow beyond 12 inches (Fig. 1B). The impulse rate continued to decrease until the suspension distance reached about 84 inches, however, and even then the rate was still slightly higher than the background reading obtained in the empty steel drum. High humidity above the unprotected water surface may account, at least in part, for the slow decay shape of the curve and the high background reading which occurred when the meter was suspended above the pool.

Some of our studies, of course, were made on field soils. In one instance we determined the relation of i.p.m. to the thickness of a wall of silt loam soil whose moisture content was about 37 percent by volume (Pv). We did this by supporting the meter on its side in a soil pit with the bottom pushed up against a smoothed wall.

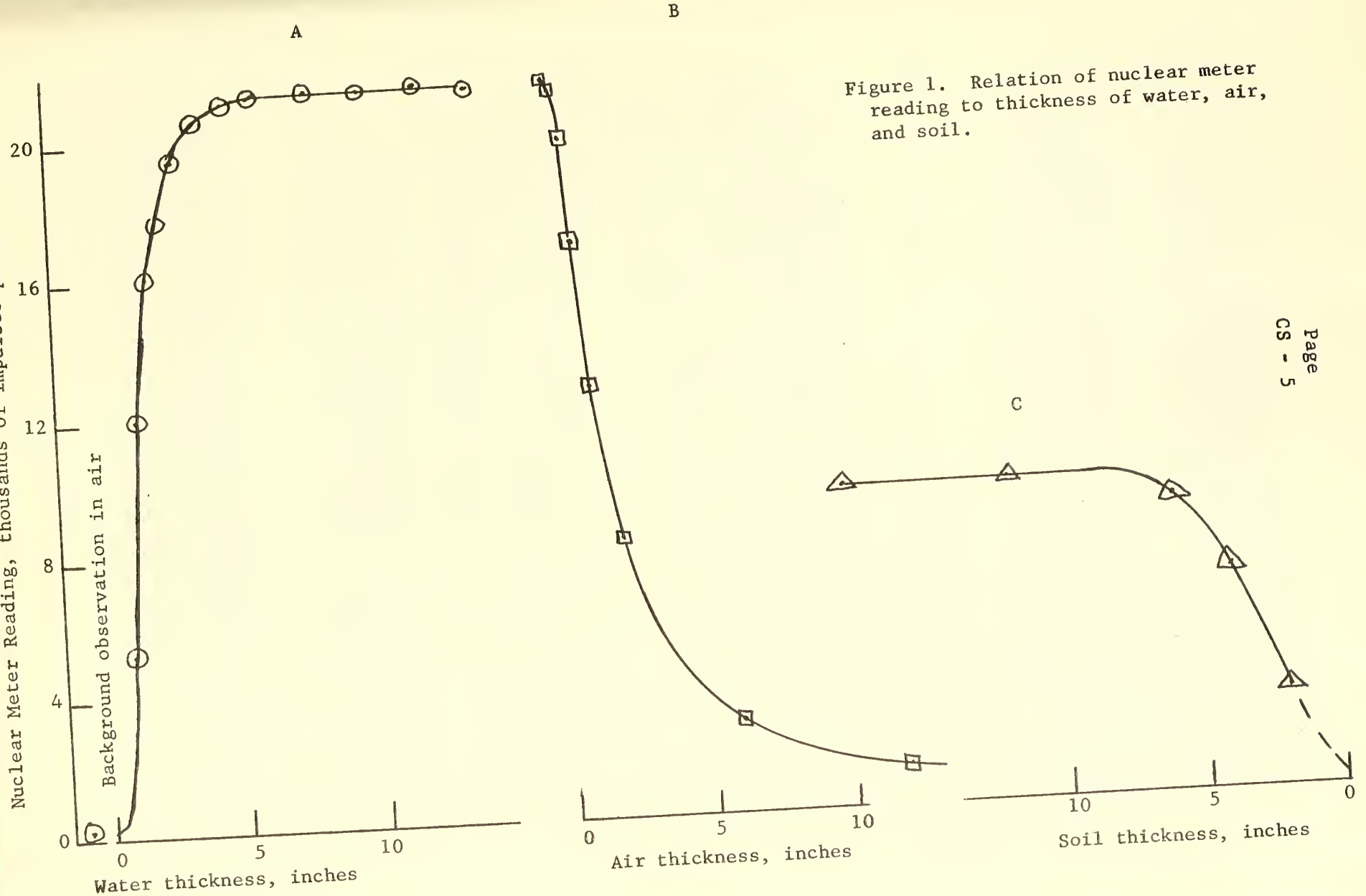

Figure 1. Relation of nuclear meter reading to thickness of water, air, and soil.

By excavating another pit nearby and by removing the intervening soil by measured increments, we found that the impulse rate was low when the wall was only two inches thick, that the rate increased rapidly as the thickness of soil increased up to 6 inches and that it leveled off at a moderate rate beyond a soil thickness of about 8 inches (Fig. 1C).

From these results it appears that the volume of material that is measured by our nuclear surface moisture probe ranges from a minimum radius of 5 inches over water, to a maximum of 12 inches in the air, and that the radius of the effective volume of a soil containing some moisture will vary between 5 and 12 inches depending upon soil moisture content.

III. Subsurface Water Management — by Ronald Z. Whipkey

A. Determining permeability of forest soil.

Percolation, transmission, permeability, gravitational water movement, and some other similar terms have been much used in the literature of the past 30 years to describe soil water movement in forest soil. Generally these terms are all used to describe the downward movement of water through the soil after infiltration has taken place. The capacity to transmit water is possibly the most important physical property of soil that is studied by forest watershed researchers, but up to the present time little effort has been expended in obtaining quantitative permeability values.

Soil permeability has proven to be a valuable index of agricultural soils for drainage design and for quantitative description of these soils. The simplest situation is drainage of a water saturated soil. The readiness with which soil drains under saturated conditions is termed hydraulic conductivity. Here the velocity of flow is proportional to the driving force, which is "hydraulic head gradient" or "potential." The proportionality constant, written simply as "K", is the above-mentioned hydraulic conductivity (7).

The movement of water under unsaturated conditions is a more difficult problem although under natural conditions it perhaps occurs more often than does movement of water through a saturated soil. Here the movement is more nearly proportional to soil water content and the proportionality constant is termed capillary conductivity--expressed as "k".

In both situations much work has been done toward obtaining approximate and exact solutions of the flow equations. Admittedly, the mathematical notation used for description and the numerical techniques used for solution are not the easiest to understand or to solve, yet a review of the literature in this subject can be

rewarding. This writer has found that most of the voluminous literature is based simply on a theoretical or an experimental expansion of the original concepts of Buckingham, and in later years, of L. A. Richards. These papers were an attempt to generalize soil water movement in much the same manner as flow of heat through solids or electricity through appropriate conductors under potential conditions. The 1907 paper by Buckingham (3) and the 1928 and 1931 papers by L. A. Richards (5, 6) are quite enlightening and are straightforward discussions of the phenomena of soil water movement. In the writer's opinion, the more recent work done in solving the original Richard's equation by use of the Diffusion-type equation is perhaps the most valuable contemporary quantitative work in this field.

The contributions of many workers have been summarized by J. R. Philip (4).

So far these physical equations contain only a quantitative expression of hydraulic or capillary conductivity. This has proved to be quite a stumbling block. Agricultural workers have used various well and analog techniques to obtain "K" values for their problem areas. Where the work has been carefully carried out, the well method (auger hole, piezometer or tube technique) seems to have given good values of flow for determination of representative "K" values. Don Kirkham has made a very solid contribution in this area, with his work in determination of K-values and solution of flow equations and drain tile spacings. Kirkham, incidentally, has based many of his solutions on analagous situations in heat flow and electrostatics.

When we first became interested in the techniques used for expressing flow rates in agricultural soils, we hoped to try the piezometer technique on our forest soil for determination of K. However, many observations of field and tank conditions showed that this would be doomed to failure, for seldom if ever did the soil wet up sufficiently to give back-pressure and a resultant rise in the small-bore wells. We also learned that the geometry of the system and the puddling and polishing of the pipe cavity were factors very difficult to control. Therefore, we decided against using any of the standard field procedures and developed our own "pit-trough" method described in previous issues of this report.

At the present time we are investigating a new technique which appears to be well-adapted to use in forest soil. It was developed by an A.R.S. engineer, Dr. Herman Bouwer (1,2). This technique, called the double tube method appears to be based on the double-ring infiltrometer. Here, the analogy ends.

Bouwer has researched his technique well and has developed a sound physical theory for it. The big advantage for forest hydrologists

is that the method is used in dry soils, with water being added during the run. The rate of movement from the soil into the inner ring after the system has reached equilibrium is the hydraulic conductivity "K".

It must be realized that this is not true saturation because the wetting takes place over a period of only several hours - and we know some soils must be under water for at least a year or more before true saturation takes place. However, the "K" value obtained from this technique (estimated by one drainage researcher as 90 percent of true saturation) is more nearly indicative of that in shallow field soils where wetting and drying occurs naturally.

We will not attempt to condense the theory and technique into the confines of these pages because the method is adequately described in two of Bouwer's recent articles (1,2) which any interested researchers can readily find. In addition, a more condensed version will soon be published in the ASAE Proceedings.

We have corresponded with Dr. Bouwer and talked with an engineer familiar with the technique and find the following:

1. The technique is backed by sound physical theory, model studies, and field studies.

2. The technique does not require a water table.

3. With a 3-man crew three set-ups can be run concurrently. Depending on the wettability of the soil, one to two K determinations can be made daily per set-up.

4. The same hole can be used to determine the value of K at greater depths.

5. The technique, if conducted properly, gives a clean undisturbed soil surface through which the water infiltrates. The water flows only through the soil and not through a cavity or perforated pipe. This should reduce the confounding of flow values that occurs when well-cavities are used.

6. Calculations can be made in the field. Only a planimeter is necessary for solution of the height-time integral. This should be an attractive feature for those researchers unacquainted with mathematical techniques of integration.

We feel this is the method we have been searching for and hope to report on it in more detail in the next several issues of the report.

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IV. Study Plans

We like the suggestions of Clark E. Holscher, Chief, Branch of Forest Soil and Water Research, regarding study plans (see his 4300 memo of March 11, 1963). Accordingly we are including the titles and objectives of our active studies.

A. Forest Restoration and Watershed Management On Strip Mine Lands (Reduction in Surface Mining Damages to Forest Resources by Improving Mining Procedures and Rehabilitation Measures.)

See sections B & D in I.

B. Management of Storm Runoff. (Management of storm runoff and improvement of water yield.)

1. Subsurface stormflow movement through forest soils in eastern Ohio.

Objective: To get enough facts on the movement and behavior of subsurface water in various geologic and soil areas to aid watershed technicians in making management decisions on areas that have large volumes of subsurface stormflow.

2. Streamflow from the Dover Experimental Area.

Objective: To determine, primarily, the shape and the height of the peak of storm hydrographs from relatively undisturbed hardwood forest areas in eastern Ohio.

3. Measurement of gross precipitation on the Dover Experimental Area.

Objective: To determine the amount, variability, and the depth-area-intensity-duration relations of gross precipitation on the Dover Experimental Watersheds.

4. Soil and air temperatures on a forested ridge within the Dover Experimental Area.

Objective: To determine the temperatures involved in the loss of water by the evaporation and transpiration processes at various points in Ohio's forested areas.

5. Evaluate Nuclear-Chicago subsurface moisture probe, serial No. 136.

Objective: Conduct applied research to determine the applicability, variability, accuracy and operability of commercially available nuclear equipment for measuring subsurface soil moisture on the heterogeneous and layered soils of forest, brush, and related range watershed lands.

6. Analysis of streamflow records from Tar Hollow Creek in Southeastern Ohio.

Objective: To relate the streamflow characteristics of Tar Hollow Creek to the physical features of its water catchment area and to compare these characteristics with those from agricultural watersheds nearby or with those from forested watersheds in other areas.

7. The characteristics of a coniferous plantation that are most closely related to tree growth and water available for streamflow.

Objective: To find some basic stand characteristics of a coniferous plantation in east central Ohio that are closely related to timber growth and to water available for streamflow.

8. Precipitation variability on a small northerly slope in east central Ohio that was planted to pine about 1943 (Palermo).

Objective: To determine the variability and probability of the amount of gross rainfall and snowfall on the Muskingum Watershed Conservancy District's Davis Tract pine plantation.

9. Evaluate Nuclear-Chicago surface moisture probe, serial No. 75.

Objective: To conduct applied research to determine the applicability, variability, accuracy, and operability of commercially available nuclear equipment for measuring surface soil moisture on the heterogeneous and layered soils of forest, brush, and related range watershed lands.

10. Evaluate Nuclear-Chicago subsurface density probe, Serial No. 103.

Objective: To conduct applied research to determine the applicability, variability, accuracy, and operability of commercially available nuclear equipment for measuring subsurface soil density on the heterogeneous and layered soils of forest, brush and related range watershed lands.

11. Evaluate Nuclear-Chicago surface density probe Serial No. 131.

Objective: To conduct applied research to determine the applicability, variability, accuracy, and operability of commercially available nuclear equipment for measuring surface soil density on the heterogeneous and layered soils of forest, brush, and related range watershed lands.

12. The relation of soil moisture content to distance from tree in a coniferous plantation.

Objective: To characterize the soil moisture profile under a young, vigorously growing coniferous forest plantation in east central Ohio.

13. Measuring subsurface soil density on the Davis Tract (Leesville Lake) soil moisture study plots near Palermo, Ohio.

Objective: To determine the uniformity in dry density measurements made with a nuclear subsurface soil density meter:

a. At nine 1-foot depth intervals per tube,

b. In three tubes per plot,

c. On seven plots per block,

d. In two blocks within the coniferous plantation on the Davis Tract.

14. Variation in individual observations made with nuclear soil moisture and density measuring equipment.

Objective: To determine the variation that may occur among individual observations made with a nuclear soil meter and to characterize the distribution of these observations.

15. Nuclear measurement of the surface density and moisture content of Ohio Power Company's storage pile of coal near Beverly, Ohio.

Objective: To compare surface density and moisture measurements made with nuclear equipment on a large pile of stored coal with concomitant measurements made by the California sand cone method and by gravimetric core samples.

16. Effect of natural litter, layers of plywood, ground surface smoothing, and distance suspended above ground upon the readings made with a P-21 surface moisture and a P-22 surface density nuclear meter.

Objective: To determine what effect site preparation has on the readings made with the nuclear surface moisture and density meters owned by the Central States Forest Experiment Station.

17. The effect of type of access tubing upon the magnitude of readings made with a subsurface neutron soil moisture meter.

Objective: To determine the magnitude of differences between means of readings made with a subsurface neutron soil moisture meter in different kinds of access tubing surrounded by air or water.

SEMIANNUAL REPORT
Division of Watershed Management Research
Intermountain Forest and Range Experiment Station

October 1962 - March 1963

DIVISION

Several matters of general interest developed during the past few months. Planning for the Forestry Sciences Laboratory at Logan, Utah is progressing on schedule, and a construction contract is to be awarded in June.

Ronald K. Tew, on leave for the past two quarters pursuing graduate work at Utah State University, has returned to duty with the Water Yield Improvement project at Logan. Dr. Nedavia Bethlahmy has been promoted and transferred to Boise, Idaho as leader of Project 1602 (Soil Stabilization). We welcome him to our Station. Harold Haupt has been promoted and transferred to Moscow, Idaho as leader of Project 1601 (Snowmelt Flood and Sediment Reduction).

Otis Copeland attended the Federal Interagency Sedimentation Conference held at Jackson, Mississippi, January 28 - February 1. He presented a paper titled "Land Use and Ecological Factors in Relation to Sediment Yields." As a matter of information to watershed management researchers, 91 papers were presented. Of these, only 24 papers dealt with origin, source, production rates, or control of sediment by land management practices or modification of uses. The other 67 papers represented engineering and other interests in measuring, predicting, storing, and handling the erosion-sediment problem after it developed either from eroding slopes or degrading channels.

Publications

Copeland, Otis L. Jr. 1962. Relation of forest diseases to soils and soil management. Fifth World Forestry Cong. Proc. 1960, I: 518-524, illus.

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Merriam, Robert A. and Otis L. Copeland. 1963. Comments on neutron soil moisture probe efficiency and sensitivity. Soil Sci. Soc. Amer. Proc. 27: 106-107.

Haupt, H. F., H. C. Rickard, and L. E. Finn. 1963. Effect of severe rainstorms on insloped and outsloped roads. U.S. Dept. Agr., Forest Serv., Intermountain Forest and Range Expt. Sta. Research Note INT-1, 8 pp., illus.

1601 - SNOWMELT FLOOD AND SEDIMENT REDUCTION PROJECT

Snowmelt Rate Study

Snowpack water forms an important reservoir of streamflow for the Columbia River Basin. Demands on the watershed to produce both timber and water in sufficient quantity and good quality require an understanding of the effect of timber removal on snowmelt rates.

A study of snowmelt in a western white pine forest in northern Idaho has shown that average snowmelt rate (SM_a), based on elapsed time in days required for the maximum snowpack water content to disappear, is influenced by relative warmth of snowmelt season (D in $\frac{\text{degree days} > 35°F}{1000}$), time from January 1 to beginning of snowmelt (T_a in days), elevation (E in $\frac{\text{feet}}{1000}$), aspect (A measured in $\frac{\text{degrees}}{100}$ clockwise from north), slope (S in percent), and forest canopy density (FCD in percent). The regression equation for average snowmelt rate in inches per day is:

$$SM_a = 1.727 - 0.065(A) - 0.636(FCD) + 0.712(FCD)^2 - 0.348(FCD)^3 + 0.034(E)(FCD) + 0.068(A)(FCD) + 0.038(S)(A) + 0.502(T_a)^2 + 0.063(E)(T_a)^2 - 0.292(FCD)(T_a)^2 - 2.577(D) + 0.979(D)^2.$$

This equation shows that the effect of timber cutting on the average snowmelt rate varies by aspect, elevation, time at which melting begins, and initial density of the forest canopy.

Maximum snowmelt rate (SM_m) is the greatest decrease in snowpack water between any two consecutive measurement dates divided by the elapsed time between these measurements. T_m is the time in days from January 1 to the beginning of the maximum snowmelt period. Maximum snowmelt rate in inches per day is expressed by the following regression equation:

$$SM_m = 4.217 + 0.004(E)^3 - 0.793(FCD)^2 + 0.526(FCD)^3 + 0.054(E)(A) + 0.728(T_m) - 0.050(A)(T_m)^2 - 6.610D + 2.303D^2.$$

This equation shows that the effect of timber cutting on maximum snowmelt rate varies with initial density of the forest canopy. It further shows that maximum snowmelt rate is principally a function of lateness of the winter or delay in beginning of melting and rate of warming of the general air mass after melting begins.

Paul E. Packer
Edward R. Burroughs, Jr.

1602 - SOIL STABILIZATION PROJECT

Erosion and Sedimentation in the Boise Basin Experimental Forest

This past winter the final analysis of the Bannock Creek sedimentation study was completed. The field work was conducted on moderate to steeply sloping terrain with relatively short slope distances from channel bottom to ridgetop. Here is a synopsis of what was learned: From the inception of the ponderosa pine cutting study in 1953 until 1960, erosion and sedimentation on 16 small watersheds were held in check reasonably well because of careful advance planning, close supervision of logging, and prompt application of intensive post-treatment measures. Sediments that reached the water courses originated primarily on haul roads. The closeness of a road parallel to a channel affected the frequency with which sediment flows reached that particular channel. Sediment flows reached channel bottoms through undisturbed buffer strips averaging 8 feet wide, but did not reach channels if the strips were more than 30 feet wide. By the end of 1956, the major portion of the flows "in route" toward water courses had halted. As expected, sediments moved at a faster rate down a channel with perennial streamflow than in channels with ephemeral flow.

Road Fill Slope Stabilization

No sooner did we report last fall on the installation of 56 runoff plots, when disaster struck. In October, 1 month after applying the seed and mulch treatments to the plots, severe rainstorms (blown in from the Oregon coast) hit central Idaho. The runoff plots with steel frame borders, all located below the lip of the road shoulder, were either displaced downhill or obliterated by intensive fill slumping. A total of 15 plots was lost completely as far as future value and a few others, although intact, have doubtful value for soil loss measurements. However, 38 plots should still provide good results on seedling survival and cover establishment.

The October storms have special hydrologic significance. From the 6th to the 15th, three rainstorms of 8-, 38-, and 87-hours' duration occurred in rapid succession in the vicinity of the study haul road. Rainfall produced by these storms varied from 7.60 inches to 9.99

inches and was unprecedented relative to total amount. Needless to say, it caused severe damage even on sections of the study road "put to bed" for the winter.

Specifically, the secondary haul road had (a) been in existence less than 6 months, (b) traversed a steep mountain with slopes generally exceeding 60-percent gradient, and (c) left exposed, in most instances, an 8- to 14-foot cut bank of granite rock overlain by a shallow soil mantle, generally less than 20 inches in depth. Part of the road was outsloped and ditched; another part was insloped with cross ditching on outcurves, only.

The survey report, the highlights of which are presented in Research Note INT-1 (1963), indicated that insloping a roadbed of the type described above is more desirable than outsloping it as an erosion prevention measure. Specifically, the inslope should be designed to lead storm runoff away, as much as possible, from the long fill on the vulnerable incurve of the road. Where culverts are to be used in major ravines, they should be located on the original water grade so that they do not discharge on the fill of the incurve but drain into the original channel. Where earthen cross ditches are to be used, they should be located to discharge their flows on the outcurve of the road. Below the outcurve, the undisturbed sideslope will tend to absorb road drainage and retard sediment flows before they reach a ravine or stream.

Checking Seed Dispersion on Road Fills

An interesting sidelight of seeding trials on road fills in the field, was that the surface of a newly constructed fill usually crusts over and becomes relatively hard and compacted. By late autumn, when climate favors seeding for erosion prevention, seed broadcast on the fill literally bounce off the crusted surface and down onto undisturbed forest floors. To study this phenomenon, model "road fill slopes" were set up in the laboratory on which were tested several soil-surface treatments for arresting downward movement of broadcast seed. Results indicated that seeding upon mulch already in place, "pockmarking" the soil surface, wetting the surface, and spreading wetted seed, reduce seed dispersion on crusted slopes. The relative effects on the downward movement of cereal rye and sweet-clover seed are shown in the table below. Less pronounced differences were observed with smooth bromegrass and intermediate wheatgrass seed.

Fill slope and seed treatment	Seed retained--mean[1]	Statistical significance[2]
	Percent	
Dry soil, unchopped timothy hay, dry seed	99.9	a
Wet soil, surface holes, wet paper netting, dry seed	96.8	ab
Wet soil, wet paper netting, dry seed	96.6	ab
Dry soil, dry paper netting, dry seed	92.8	bc
Dry soil, surface holes, dry seed	91.5	c
Wet soil, surface holes, dry seed	74.2	d
Dry soil, wet seed	72.9	d
Wet soil, dry seed	43.0	e
Dry soil, dry seed (control)	23.6	f

1/ Out of a possible 200 seeds, replicated 8 times.

2/ Means followed by letter "a" are significantly different from those means not having "a"; those followed by "b" are significantly different from those not having "b", etc.

Harold F. Haupt
W. Joe Kidd, Jr.

1603 - WATERSHED REHABILITATION AND PROTECTION

Effects of Soil Properties and Vegetal Characteristics on Infiltration Capacity and Soil Stability

Soil erosion control and flood prevention depend on proper management of vegetation and soil. Investigations of the influences of vegetation characteristics and soil properties on infiltration capacity and soil stability are necessary to provide guidelines for sound management of range watersheds and to provide basic information for research in watershed rehabilitation and other land treatments.

Multiple regression analyses of data from 164 infiltrometer plots on central Utah summer range were completed. A combination of bulk density of the surface 4 inches of soil, air-dry weight of vegetation, air-dry weight of litter, and slope gradient accounted for 55 percent of the variance in 30-minute infiltration rates under a simulated rainstorm of 5 inches per hour. Moisture content of undisturbed soil cores from the 1- to 2-inch depth at 60-centimeters tension accounted for an additional 6-percent variance. Clay content, organic matter content, and aspect collectively accounted for still another 4-percent variance. No significant additional variance was explained by the remaining 30

measured variables, although most of these were significant in simple correlations with infiltration. The standard error of estimate of a prediction equation containing the eight significant independent variables is 0.379 inch of water retained on the plot site. A simpler equation based on bulk density, vegetation weights, litter weights, and slope has a standard error of estimate of 0.423 inch of retained water.

Sediment eroded from these same plots during a 30-minute application of simulated rain at an average intensity of 5 inches per hour was most closely correlated with percent of soil surface exposed to direct raindrop impact. This single variable explained 52 percent of the variance in the logarithms of sediment eroded. Logarithms were used because the distribution of values of sediment eroded was strongly skewed and a more nearly normal distribution was obtained by transforming them to logarithms. Plot slope gradient explained an additional 10-percent variance and bulk density of the surface 2 inches of soil another 4 percent. These three variables explained 66 percent of the variance in the logarithm of eroded sediment. No significant additional variance was explained by the remaining variables with the exception of plot runoff. If the amount of runoff during the test is considered as an independent variable, a total of 72-percent variance can be explained. This fourth variable is of questionable value in characterizing soil stability but does indicate the net effect of volume of overland flow on the amount of sediment eroded.

During the past summer, infiltration and soil stability were studied on the Davis County Experimental Watershed in northern Utah and on the Gravelly Mountains in the Beaverhead National Forest in southwestern Montana. No results are available as yet from the Davis County study, but simple correlation coefficients have been calculated for 42 variables on the 86 infiltrometer plots on the Gravelly Mountains. These variables include ground cover density, air-dry weights of vegetation and litter, and weights of soil cores from various depths at saturation, at 20-centimeter moisture tension, at 60-centimeter moisture tension, and oven-dry. Infiltration rates during 30-minute applications of simulated rain are more closely correlated with weights of moist soil cores from the surface 2 inches of soil than with the other tested variables. At 20-centimeter moisture tension, the correlation coefficient is -0.64 and at 60-centimeter moisture tension, the correlation coefficient is -0.65. The highest correlation between infiltration and soil bulk density is -0.63. This suggests the possibility of using moist soil core weight rather than soil bulk density to predict infiltration capacity, thereby avoiding the necessidy of oven-drying. Of the cover characteristics, air-dry weight of litter is most highly correlated with infiltration ($r = 0.59$) and air-dry weight of live vegetation is next most highly correlated ($r = 0.53$).

Sediment eroded during 30-minute applications of simulated rain was more closely correlated ($r = 0.76$) with percent of soil surface exposed to direct rain impact than with any other variable. Saturated weight of soil cores from the surface 2 inches of soil was the soil variable most closely correlated with sediment eroded ($r = 0.54$).

At this stage of analysis, it appears that results of the southwestern Montana study will be similar to those obtained in central Utah. In both cases, sediment eroded depends primarily on percent of soil surface exposed and secondarily on soil properties. Also, in both cases, infiltration rates are limited primarily by soil properties and secondarily by cover characteristics. Weights of live vegetation and litter provide slightly better estimates of infiltration rates than does ground cover density.

The southwestern Montana data will be subjected to multiple regression analyses so that the relative influences of the site factors in combination on infiltration and soil stability can be defined. The results of these analyses will provide a basis, in the form of prediction equations, for estimating infiltration capacity and soil stability on these particular range soil-vegetation complexes from readily measurable site characteristics. The effects of changes in vegetation and soil properties on infiltration capacity and soil stability can thereby be estimated quantitatively, permitting indirect evaluation of the effects of grazing and other land treatments on erosion and flood control.

Moisture Conductivity in Unsaturated Soil

Control of overland flow and soil erosion depends, to a large degree, on adequate infiltration capacity. Basic studies of the nature of the infiltration process are needed to support research on infiltration problems. Among the several variables that affect infiltration rates are temperature and unsaturated conductivity. Further research on the interaction of these is needed for better understanding of the infiltration process.

During the past year, we determined unsaturated conductivities of four soil cores at soil moisture tensions from 0.05 to 0.5 atmospheres and at 12°, 20°, 30°, and 40°C. In a poorly aggregated loam, soil moisture conductivity at various tensions tended to increase with increasing temperature. On the well-aggregated clay soils, conductivity increased with temperature, but only at low moisture tensions. At greater tensions, conductivity was inversely related to temperature. This is believed to be due to the inverse relation between soil moisture content and temperature at these tensions. At higher temperatures, the soil at a particular tension contains less water and therefore less conducting area than at lower temperatures. Moisture content data at the four temperatures and at various tensions

are presently being collected so that the relations between temperature and conductivity at constant moisture content can be investigated. Results of this study are expected to lead to improved understanding of the infiltration process and other related unsaturated flow phenomena.

R. O. Meeuwig

1604 - CHANNEL STABILIZATION PROJECT

Relation of Bed Characteristics to Flow Characteristics in Steep, Rough, Natural Open Channels

This study proposes to relate bed characteristics to flow characteristics in steep, rough, open, natural channels. The class of streams being studied are those in mountainous regions paved with large cobbles and boulders. In this sense, the streambeds will be assumed fixed.

Piezometric installations were made in late spring, 1962. Discharge, water slope, and other hydraulic data were obtained as the flow decreased. During this time, photographs, notes, and visual observations at each of the 13 sites were obtained. Equipment was developed for measuring bed roughness. In late summer, when the flow was relatively low, detailed roughness measurements were taken.

The data are now being analyzed with the aid of an IBM 1620 digital computer to obtain a statistical representation of the bed. Relative roughness, intensity or spacing of the roughness elements, and a phenomenon designated as the "step" formation are being considered. This "step" formation appears to be a natural energy dissipator, and further analysis of its associated parameters is being made. Work is being done on a mean velocity formula, of the Chezy form, that includes relative roughness, a channel shape factor, and intensity, as well as the slope, water depth, and velocity.

Otis L. Copeland
Harl Judd (cooperator
under Cooperative Aid Project
with Utah State University)

1605 - WATER YIELD IMPROVEMENT PROJECT

Because of some reorganization of this project, we decided to present brief sketches of some of the current studies.

Effects of Topographic and Climatic Factors on Free-Water Evaporation in Mountainous Terrain

Within the Great Basin drainage system, evapotranspiration losses have been variously estimated to be from 75 to 90 percent of the amount

of precipitation that reaches the land surfaces. Of this amount, 50 percent may be lost to the atmosphere by evaporation alone; but quantitative information concerning evaporation in mountainous terrain is lacking. This study of free-water evaporation is only one segment of the overall problem. It is, however, one that is basic to an understanding of the forces and factors involved and that is necessary to establish parameters for this segment of the hydrologic cycle.

Results obtained during the first year of this 3-year study of evaporation and associated meteorological factors at 12 sites with diverse elevation, topography, and vegetation have revealed that the range in evaporation over mountainous terrain is great. Evaporation from Weather Bureau class A pans during a 98-day period, from June through September, 1962, varied from 20.1 to 32.7 inches. These values represent 81 and 131 percent of the mean seasonal value of 24.85 inches for all 12 sites. Maximum daily rates varied from 0.330 to 0.574 inch, and maximum hourly rates on selected days ranged from 0.018 to 0.040 inch at the various sites. Total water loss by evaporation from a free-water surface exceeded summer precipitation eight- to tenfold. At the control station in the Great Salt Lake Valley, this 98-day loss was equal to 55 percent of the total annual loss.

Evaporation rates above timberline on exposed ridges and in the oakbrush zone at elevations from 5,000 to 7,500 feet above mean sea level were higher than in the aspen and aspen-fir types at elevations from 7,000 to 8,500 feet. Topography and vegetation at the various elevations modify temperature, wind movement, and radiation; and, generally, the highest evaporation rates occurred at sites with the highest mean air and water temperatures, wind velocities, and longest daylight periods.

Of the several variables affecting evaporation, wind appears to be the dominant meteorological factor. Two weather stations, both located in the same 462-acre watershed, substantiated this. On the ridge at the head of the watershed, wind movement occurred predominantly during daylight hours, averaging 127 miles a day; and 81 percent of the total daily evaporation took place during the daylight period. Near the mouth of this watershed, along the stream channel, winds were light during the day but strong down-canyon breezes predominated at night. Sixty-eight percent of the daily evaporation occurred during the night hours at this station.

Two stations, both in the aspen type but with opposing north and south exposures, had nearly the same evaporation for 75 percent of the days. During the remaining period of measurement, evaporation at one or the other of the stations was clearly shown to be the result of wind speed and direction. Apparently, the greater loss of water from the station with a south exposure was due to a greater number of days with strong southerly winds.

The study has indicated thus far that mean daily air and dew point temperatures and wind movement can be used to predict evaporation loss with a fair degree of accuracy. Furthermore, reductions of water loss by evaporation, and, conversely, increases in water yield, may be achieved by watershed treatments that lower temperature and wind movement at a given site.

Disposition of Precipitation in the Aspen Type of Northern Utah

Water yielded from mountain streams in the Great Basin is barely adequate to meet demands of the present population. As agricultural, municipal, and industrial growth continue, the supply of delivered water must also grow. This may be achieved through manipulation of vegetation on the higher water-yielding lands of the Great Basin drainage, and the aspen type occupies a sizeable amount of acreage of this water-yielding zone. The present study is designed to provide an indication of the water increases that may be obtained where aspen is removed from an area.

On a fairly uniform site, neutron meter measurements in 1962 indicated the following moisture contents in 10 feet of soil profile for four conditions of plant cover at the time of maximum soil moisture depletion before autumn precipitation began to recharge the soil: bare soil--34.37 inches of water; herbaceous vegetation only (aspen removed)--32.58; aspen stand with herbaceous understory removed by grazing--22.10; aspen stand with undisturbed herbaceous understory--15.48 inches of water.

This information is indicative of the relative magnitude of water loss due to transpiring vegetation and direct evaporation from the soil surface. It will, when strengthened by more complete data for precipitation disposition throughout the year, permit evaluation of what may be gained by altering the aspen cover on sites in the higher elevations of the Great Basin.

As this report is being printed, the writer is obtaining snowpack evaporation data at the study site located at 8,300-feet elevation in the Wasatch Mountains.

Transport of Water through Functional Root Connections in Aspen and Oakbrush Clones in Utah

Transport of water through roots of connected stems in clonal vegetation has been studied very little,[1/] but a better understanding of this phenomenon may lead to knowledge directly pertinent to control of

1/ Acknowledgment is made to faculty and graduate students of the Dept. of Forestry, University of Michigan for ideas and information underlying portions of this study.

such vegetation when improvement of water yields is an objective. Extensive stands of quaking aspen and Gambel oak that occupy mountain watersheds of the Great Basin may be more capable of depleting soil moisture than is usually understood. For this reason, this study to determine the extensiveness and effectiveness of clonal root connections in aspen and oakbrush clones has been started.

Twenty-seven aspen clones and one oak clone were injected with various tracer substances, and the extensiveness of the root connections was evaluated by counting the number of stems that received the tracer. Sodium arsenite was translocated to 26 oak trees from an injection into one donor stem, and 291 aspen stems received tracer material from 49 donors. Subsequent analyses of the soils in which these clones were growing indicates that the number of stems connected by functional roots is inversely proportional to the bulk density of the soil and directly proportional to the percent of soil greater than 2.0 millimeters in size.

Information from this study has provided valuable insight into aspects of clonal vegetation that must be considered when eradication of aspen or oak is contemplated, and it also indicates that water may be transported considerable distances through functional root connections. Cutting streamside vegetation, if it is clonal, may not actually result in decreasing water losses from the streamside because functional root connections may persist and continue to serve the transpiring parts of the clone farther away from the stream. Cutting may, in fact, result in greater losses because of increased exposure of the site to evaporative forces.

Morphology and Growth Characteristics of Aspen Root Systems[2/]

As emphasis on manipulation of vegetation for the purpose of increasing water yields increases, it becomes imperative that adequate knowledge concerning plant root system characteristics be obtained. The water economy of quaking aspen in the Intermountain Region is currently under study, and considerably more knowledge of its rooting habits must be obtained before a genuine understanding of water use by this species can exist.

Excavation in several different Utah aspen clones during 1962 substantiated the knowledge obtained about root connections with this species in other parts of the United States.[3/] Clones were excavated on clay, loam, and gravelly loam sites. In such heavier soils as clay, root connections appeared to deteriorate more easily and more frequently than in more permeable soils.

2/ This study is being conducted by G. F. Gifford, a graduate student at Utah State University, under a cooperative aid agreement between the Station and the University.

3/ See footnote 1/.

Persistence of root connections in aspen clones relates importantly to whatever treatment may be imposed on aspen for increasing water yields. The knowledge that stems may tend to disassociate from one another after a time on tight soils may bear considerably on the pattern of water extraction by aspen as well as on what methods may be most successful in eradicating the species on a given site.

At present, root suckers of trembling aspen are being grown under various combinations of light intensity and temperature in the controlled environment chambers at Utah State University. Results from this part of the study may indicate the relative importance of light, temperature, and culture medium on the success of aspen root suckers.

Precipitation Disposition in the Oakbrush Type

Neutron meter access tubes will be installed in selected plots of oakbrush on the Davis County Experimental Watershed so that measurements of soil moisture depletion can be obtained. Collections of annual precipitation data and interception, stemflow, and runoff measurements will make possible the construction of the water balance for this type. Twenty-seven access pipes have already been installed on erosion plots in the oakbrush type, and these will be used as sample points for our neutron meter this summer.

Roughly 2.3 million acres of mountain-brush vegetation occur in the portion of Utah that drains into the Great Basin. An average of 22.3 inches of water falls on this type in the Utah part of the Basin, so it is important that we find out how much water the oakbrush uses.

Reduction and Elimination of Aspen and Oakbrush in the Great Basin

If studies indicate that aspen and oakbrush, two types of importance in the water-yielding zones of the Great Basin, utilize more water than do other types of vegetation that might be used to replace them, we will have to know how to control sprouting if replacement attempts are made. The feasibility of removal must be weighed against the benefits that may be derived; but, nonetheless, different methods of removal must be tested.

Following is a partial list of control measures that we plan to evaluate. We would appreciate additional suggestions from those readers who have had experience in control of trembling aspen and oak. (Gambel oak belongs to the white oak group.)

Type of control	How obtained
Chemical	Foliar spraying; cutting, then spraying stumps; basal sprays on standing tree; tree injections.
Mechanical	Clear cutting; cabling or bulldozing.
Burning	Clear cutting, then broadcast burning; burning standing trees.

Establishment of Water Consumption Rates for Range Vegetation

In the Great Basin drainage, little work has been done on the water consumption rates of natural plant communities or of those which have been used in range revegetation. With increased concern being voiced for water of greater quantity and better quality, it is necessary that research establish relative rates of water use by all of the major vegetation types that occur in high water-yielding zones and that may be used if type conversion is effected. Establishing transpiration rates, interception rates, and stemflow characteristics is essential; and such factors as soil temperature, air temperature, relative humidity, and wind movement also need to be evaluated before manipulation and management of vegetation for increased water yields can be accomplished wisely.

Transpiration rates will be determined by greenhouse studies and by soil moisture depletion studies under field conditions. Interception and stemflow characteristics will be determined. These data will be correlated with vegetation and soil characteristics of the study areas.

Variability of Mountain and Valley Precipitation

Continuous records of precipitation have been obtained at two climatic stations on the Davis County Experimental Watershed during the past 22 years. The farmington record was obtained at the base of the Wasatch Mountains at an elevation of 4,334 feet. Rice climatic station, 3.5 miles east of Farmington, is located on a small open bench adjacent to the creek in Farmington Canyon at an elevation of 7,000 feet.

The mean annual precipitation for Farmington is 20.24 inches, and at Rice the mean for a comparable period of record is 42.01 inches. This difference represents an increase of 1-inch annual precipitation for each 122-feet rise in elevation.

Several statistical analyses were applied to these data to determine the variability or, conversely, the reliability of annual and monthly precipitation at these two locations and the relation of variability between the two elevations.

The standard deviation of annual precipitation at Farmington was found to be ±3.57 inches and at Rice, it was ±6.28 inches. The coefficients of variation, "C", of annual precipitation were 0.176 and 0.149 at Farmington and Rice, respectively. These results indicate slightly less variation at the higher elevation. Monthly values of "C" were generally higher than the annual. At Farmington, they varied from 0.351 for December to 1.027 for July, and at Rice from 0.375 for December to 0.914 for September.

In addition to the coefficient of variation, the mean relative variability factor, "v_r"[4/], was computed from the formula:

$$v_r = \frac{1}{nM} \sum_{i=1}^{n} \left[p_i - M \right] \qquad (1)$$

where $p_i \ldots p_n$ are monthly or annual amounts of precipitation for n years and M is the mean monthly or annual precipitation. Equation (1) may be written:

$$v_r = 2 - \frac{2s}{n} - \frac{2\Sigma Q_i}{nM} \qquad (2)$$

where s equals the number of months or years precipitation is above the mean and Q is the amount of precipitation during months or years with below normal precipitation. The mean relative variability factor has a maximum value of 2 (extreme variability) and a minimum value of 0 (no variability).

This statistic indicated, again, that annual precipitation at the higher elevation station was less variable than precipitation at the valley station. The "v_r" value at Rice was 0.126 compared to 0.150 at Farmington. This relation was also true for all months of the year except May and December when rainfall at Farmington is slightly less variable than at Rice.

Monthly values of "v_r" ranged from 0.299 for December to 0.764 for June at Farmington and from 0.314 for December to 0.713 for June at Rice. Mean relative variability values show more variability for monthly than for total annual precipitation, which is similar to the results obtained using the coefficient of variation.

The following table lists the several statistics mentioned above, by months, for these two stations.

4/ Schumann, T. E. W. and J. S. Mostert. 1949. Variability and reliability of precipitation. Bul. Amer. Meteor. Soc. 30(3): 110-113.

Precipitation Statistics - Farmington and Rice, 1940-1961

Month	Mean precipitation		"s"		"C"		"v_r"	
	Farm.	Rice	Farm.	Rice	Farm.	Rice	Farm.	Rice
Jan.	2.21	4.76	1.29	2.49	0.584	0.523	0.461	0.421
Feb.	1.88	4.58	1.04	2.17	.553	.474	.410	.368
March	2.29	5.12	1.04	2.14	.454	.418	.353	.322
April	2.51	4.71	1.34	2.08	.534	.442	.408	.373
May	1.98	3.78	1.31	2.24	.662	.592	.469	.476
June	1.40	2.63	1.27	2.21	.907	.840	.764	.713
July	0.37	0.71	0.38	0.49	1.027	.690	.708	.530
Aug.	1.13	1.58	.96	1.36	.850	.861	.724	.672
Sept.	.78	1.40	.69	1.28	.885	.914	.712	.654
Oct.	1.67	3.30	1.42	2.65	.850	.803	.659	.596
Nov.	2.00	4.43	1.01	2.22	.505	.501	.426	.398
Dec.	2.02	5.01	.71	1.88	.351	.375	.299	.314
Annual	20.24	42.01	3.57	6.28	.176	.149	.150	.126

When the months are arrayed according to variability of precipitation, as in the following table, precipitation from November through April is less variable than the 6-month period from May through October and that "v_r" values are more highly correlated between the two stations than are the "C" values. The correlation coefficient obtained when monthly values of "C" from Farmington and Rice are used was 0.779, while "v_r" values resulted in an "r" of 0.964.

Array of Precipitation Variability by Months

Relative variability	Rank	"C"		"v_r"	
		Farm.	Rice	Farm.	Rice
Lowest	1	Dec.	Dec.	Dec.	Dec.
↓	2	Mar.	Mar.	Mar.	Mar.
	3	Nov.	April	April	Feb.
	4	April	Feb.	Feb.	April
	5	Feb.	Nov.	Nov.	Nov.
	6	Jan.	Jan.	Jan.	Jan.
	7	May	May	May	May
	8	Aug.	July	Oct.	July
	9	Oct.	Oct.	July	Oct.
	10	Sept.	June	Sept.	Sept.
	11	June	Aug.	Aug.	Aug.
Highest	12	July	Sept.	June	June

Information of the variability of precipitation should be valuable to forecasters of streamflow who base their predictions on precipitation data, because it can indicate how reliable their estimates may be. For example, a prediction of streamflow along the Wasatch Front, made on January 1, based on the assumption that precipitation will be normal through April 1, should be reasonably accurate, because precipitation during winter months is more reliable along the Wasatch Front than during the remainder of the year.

John D. Schultz
Dale J. Pfankuch
Ronald K. Tew

1606 - RAIN-ON-SNOW FLOOD REDUCTION PROJECT

Wet-Mantle Flood

From the research standpoint, we were fortunate to experience a wet-mantle flood from the Sierra Nevada this past winter. In spite of the damage this flood caused in both California and Nevada, it gave us further useful information to use in developing methods to combat similar future events. Commencing January 28, an extensive storm occurred in the Sierra. Some snow fell at the beginning and toward the end of this storm, but most precipitation at all elevations was rain. Between January 28 and February 1, enough rain fell to cause most streams to reach flood stage. The crest on the Truckee River at Reno was estimated at 18,390 cfs. on February 1.

Our research area, the Dog Creek watershed, contributed significantly to the Truckee flow at Reno. Dog Creek rose from a preflood flow of 0.4 cfs. on January 29 to peaks greater than 800 cfs. on January 31 and February 1 as a result of precipitation in excess of 8 inches in some parts of the drainage. Prior to the rain and snow which caused this flood, only a trace of snow was on the ground below 8,000 feet. Cold air temperatures and a lack of snow cover for most of the winter, combined with moist soil from autumn rains, caused extensive soil freezing in the Dog Creek watershed. The frozen soil probably contributed to the excessive surface runoff from elevations below 8,000 feet. Above this elevation, and in protected places where snow prevented soil freezing, the great amounts of rain caused the snow to melt which also contributed to flood flow.

In summary, the past winter's flood from the east Sierra Nevada was due to excessive rain and snowmelt runoff from the highest and most protected areas and from rain on frozen soil on many of the denuded watersheds at intermediate and lower elevations. Better vegetative cover on the frozen watersheds may have resulted in a more porous type of frost, which, in turn, may have allowed greater infiltration during this flood-producing storm.

Norbert V. DeByle

Cadillac, Michigan

Isolating On-Plot Recharge From General Ground Water Basin Behavior

Definable ground water basins seem to run to pretty large sizes in the deep, coarse-textured drift materials of northern Lower Michigan. The basins on the Udell Experimental Forest are no exceptions. Indications are that from one to three sections of land should be considered for any unit watershed study. Since these would be impractical to work with, a possible alternative would seem to be some method of evaluating the ground water budget for a plot representing uniform soil and cover conditions within the basin.

In our shallow water table areas we have been able to use well fluctuations to study the effects of water table height and gradient upon ground water recession due to gravity flow. Ground water recession during periods of negligible recharge appears to be related to differences between water table slopes above and below the plot. Thus, for any well, there is a characteristic depletion curve, the slope of which varies according to the elevation and slope of the water table. By using this curve as a base flow curve and smoothing out barometric influences, we have been able to evaluate recharge within a single forest cover condition even though this condition represents only a fraction of the ground water basin.

Midwinter Recharge in Shallow Water Table Areas Accounts for Snowpack Differences

The above techniques made it possible to evaluate differences in recharge in two hardwood stands during the past winter. Snowfall from December 1 to March 15 contained 8.8 inches of water. There were no appreciable thawing periods during this time and the snowpack under a portion of the hardwood stand where the water table was about 15 feet below the ground surface contained 8.3 inches of water on March 14. On this same date the snowpack in a lower portion of the stand where the ground water was only 3 to 4 feet below the surface contained only 6.2 inches of water. Although soil freezing was negligible under the deep snow cover in both areas, there appeared to have been more snowmelt at the ground line where the ground water was nearer to the surface.

The ground water fluctuations during the winter in the two areas show at least two periods of relatively rapid recharge in the shallow water table area (fig. 1). After correcting for the changes in storage due to the inflow-outflow balance and adjusting the remaining changes for the specific yield of the soil layers concerned, the total recharge in the shallow water table area was computed to be 2.0 inches. Considering the precision of the method, this winter recharge accounts for the differences in snowpack, since no measurable recharge occurred in the deeper water table zone.

These results indicate that in the future it may be worthwhile to examine the influence of midwinter melting in such shallow water table lands on the seepage flows which sustain the base flow of streams during prolonged cold weather periods.

Cooperative Studies

Plans are now completed for a study of the topography of the water tables and the confining clay layers in the upland moraine section of the Udell Experimental Forest. Seismic refraction and electrical resistance geophysical methods will be used by the Geology Department of Michigan State University to explore this "mystery" area. The depth of the drift overburden materials is as much as 250 feet thick in this area. Up to now this has prevented us from completely delineating the four recognized ground water basins which are apparent in the surrounding outwash plain.

The Department of Soils at Michigan State University has also been helping to solve the dilemma of the deep overburden materials. Fifty- to sixty-foot wells have been used as access tubes for neutron soil moisture meter readings during the period of snowmelt and subsequent percolation of recharge waters to the water table. The delay of 30 to 60 days between the end of snowmelt and the beginning of the water table rise may not be entirely explained, but at least we will know where the water was all that time.

A Water Level Sensing Device

We recently had an opportunity to observe a demonstration of a fairly new water level sensing device and thought it worth reporting. The device is very simple in appearance, consisting of a transistorized circuit, a driving mechanism, a sensing bob, and batteries. Its primary application is to measure water levels in small-diameter wells. It is used in conjunction with any conventional water level recorder. In use, the wire with the sensing bob is passed over the recorder pulley and the bob placed in the well. When the power is turned on, the drive mechanism will be activated and the bob will be lowered until

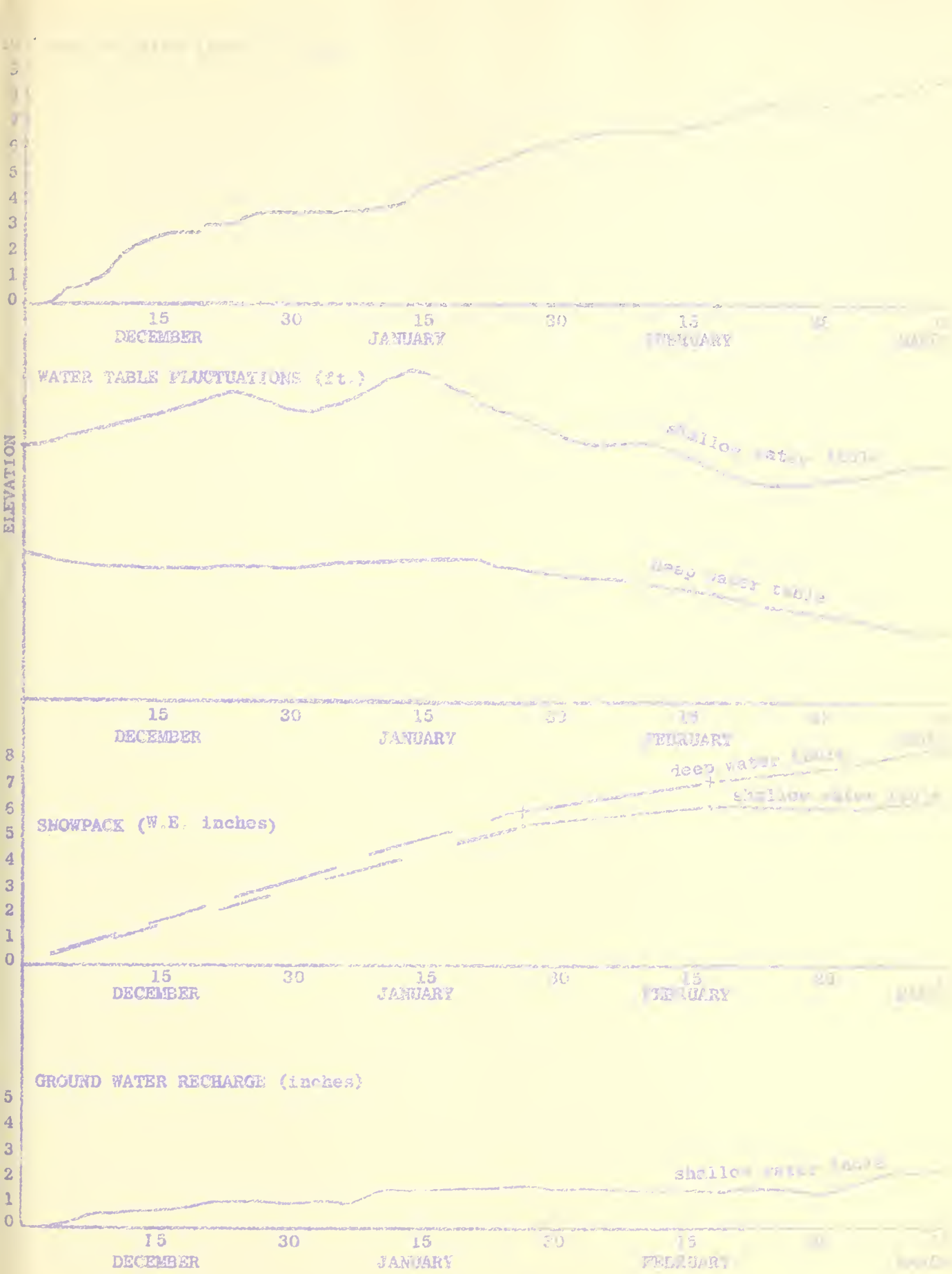


Figure 1 --Comparison of snowpack and recharge in relation to water table fluctuations

it contacts the water surface. Thereafter the mechanism will respond to any change in the water level. The manufacturers claim it is accurate within .01 foot. Sensitivity can be adjusted with a ten-position sensitivity selector. In general, sensitivity will vary with well depth and water conductivity. The device costs $195. Anyone interested in further details should write: W. G. KECK ASSOC., P. O. Box 107, East Lansing, Mich.

- Dave Striffler

- Dean Urie

Bottomless Field Lysimeters

We are presently planning a study to develop, install, and test a number of bottomless field lysimeters to measure evapotranspiration losses in certain bog areas. While working on previous studies, we found that peat samples could be taken below a water table using a caissonlike device to keep free water out of the excavation. In these bogs the water conductivity of the lower peat materials in a soil profile was so low that little water moved into the caisson as long as it was driven into compacted peat types. Hydraulic conductivity measurements show conductivities as low as 7.5×10^{-6} cm./sec., or about 0.159 gal./day/sq. ft.

When an 8-inch-diameter tube was installed in these peats to measure hydraulic conductivity, the water entered the empty tube at the rate of only a few centimeters a day, with a head difference of 50 to 60 cm. With much larger diameters, and with much smaller differences in head, as in a lysimeter, the amount of water entering the structure would be much less. We feel that the amount of water entering from the bottom would be negligible, or better yet, we think the actual amount can be determined. This should then eliminate the need for a bottom in our lysimeters. Only side walls would be needed to prevent the movement of water in and out through the more porous surface horizons.

Several problems are eliminated by using a lysimeter with only sides. The peat profile contained in the lysimeter would not be disturbed, the size of lysimeter area would not be as limited, and large trees could be included.

We're thinking of using galvanized sheet metal for the lysimeter walls. This is thin enough to cut through the soft organic soil layers, yet rigid enough to be driven. Continuous rolls, 3 feet wide, are available. This material could be unrolled in the field, the one seam fastened and sealed, and then the entire lysimeter forced into the peat. Right now, we're thinking of lysimeters about 10 feet in diameter.

Water losses from lysimeters supporting various cover types would be calculated from measurements of water table drawdown within each lysimeter. The amount of water moving into the lysimeter through the bottom can be accurately estimated by several methods. One would be the use of hydraulic conductivity measurements obtained from soil cores. A second method might involve pumping water into or out of a covered lysimeter plot. Since E-T would be controlled, the rate of water movement back into the lysimeter under different hydraulic heads could be measured.

Once the question of water movement through the bottom is settled, it becomes a matter of measurement of climatic factors and physical properties of the upper horizons of peat materials. These will allow us to translate water table changes into actual volumes of water.

We think this type of installation will work in saturated peat profiles that have a lower horizon of compacted peat materials such as some of our experimental bogs. Any comments?

Hydraulic Conductivity of Peats

Some of our preliminary field measurements of hydraulic conductivity in organic soils are presented in the following table. Just as in our other studies of physical properties of peats, we found that all peats are not the same (contrary to former public opinion). The data also indicate that not all bogs are good aquifers (which is also contrary to public opinion).

Vertical hydraulic conductivities (field measurements) of several peat and mineral soil materials

Material	K(cm./sec.)	Soil permeability class[1/]	Aquifer class[1/]
Peats			
Undecomposed moss peat			
0-10 cm.	5.79×10^{-3}	Rapid	Good aquifer
45-50 cm.	1.58×10^{-3}	Moderate	Good aquifer
Woody peat			
(45-50 cm.)	4.31×10^{-3}	Rapid	Good aquifer
Aggregated peat			
(50-60 cm.)	8.52×10^{-6}	Very slow	Poor aquifer
Herbaceous peat			
(70 cm. +)	7.54×10^{-6}	Very slow	Poor aquifer
Mineral soils			
Clean gravel	1.18×10^{-1}	Very rapid	Good aquifer
Clean sands	2.36×10^{-2}	Very rapid	Good aquifer
Fine sands	4.71×10^{-5}	Slow	Poor aquifer
Glacial till	2.36×10^{-6}	Very slow	Poor aquifer
Unweathered clays	4.71×10^{-9}	Very slow	Impervious

[1/] Soil permeability and aquifer classes, and mineral soils values, were presented by T. J. Marshall, "Relations Between Water and Soil," and by D. K. Todd, "Ground Water Hydrology."

Many bogs have peat profiles similar to the profile in the above table. In these bogs, most of the water movement occurs near the bog surface. Bogs with deep profiles of porous materials would react differently. Consequently, the water storage properties of these bog types also differ.

Our measurements also indicate little difference between vertical and horizontal hydraulic conductivities, even though certain peats had a definitely laminated structure. This may be peculiar to organic materials.

It appears that hydraulic conductivities determined by the laboratory method are a little higher than those measured in the field. This is especially true of the more dense, aggregated and herbaceous peats as illustrated in the table below.

Laboratory and field determined hydraulic conductivities

Material	K(cm./sec.)	
	Field	Laboratory
Woody peat	4.31×10^{-3}	3.34×10^{-3}
Moss peat	1.58×10^{-3}	6.99×10^{-3}
Aggregated peat	8.52×10^{-6}	5.01×10^{-5}
Herbaceous peat	7.54×10^{-6}	2.65×10^{-4}

We suspect that the higher rates are due to greater water movement between the peat and the inside wall of the cylinder. Such leaks are less likely to show up in the porous materials because of the already high hydraulic conductivity.

- Roger R. Bay

- Don H. Boelter

La Crosse, Wisconsin

Peripatetics

On the Coulee Experimental Forest we have 25 water-measuring devices of one kind or another scattered around the 2,800-acre area. Some are just off the tops of ridges; some are in valley bottoms 400 feet below. The steep slopes and lack of a planned road system limit automobile traffic from ridgetop to valley bottom except at a few places. A complete circuit of the water-measuring stations to put us within reasonable walking distance of each requires about 30 miles of travel, both on and off the Experimental Forest. And with chart changing, etc., it is more than a day's job for one man.

We have eliminated the need for making the complete circuit except after periods of surface runoff by equipping our water-level recorders with automatic tripping devices at all stations (20 of the 25) that measure only surface flow. Now we have further reduced the time and distance required to make the gage run. Last fall we acquired a "Tote-Gote" trail scooter. With "the gote" and a system of ridge-to-valley trails, we have cut distance travelled by about five times.

Study Plan

Objectives: to study the influence of plantation establishment and growth on soil moisture, snow accumulation and melt, on litter accumulation, and on bulk density and several chemical properties of the soil. Red and white pines and red oak will be studied on both north and south slopes. Norway spruce and larch will be studied on north slopes.

The various factors will be studied on plots established for this purpose on the Coulee Experimental Forest. Measurements will be taken at intervals through the years of plantation growth, starting with an open condition. Unplanted control plots will also be sampled.

Miscellany

Analysis of some old lysimeter data and of some soil moisture measurements taken last winter show that moisture percolates from wet soil continuously for as long as 4 to 5 weeks. This agrees with what Hewlett has been finding from his soil tank study. Our last year's data, taken in frozen soil, also show--and rather surprisingly to this reporter--that snowmelt produced infiltration and percolation in soil that was hard-frozen to a depth of 18 inches.

We have been able to eliminate freezing in stilling wells at springflow measuring stations by drilling 1/8-inch weep holes in the wells. This allows a continuous change of water in the well. This reduces head in the weir or flume, but adjustment can be made for it. After the winter period, the holes are plugged up.

- Richard S. Sartz

- Willie R. Curtis

Results of Watershed Rehabilitation Plantings

A series of experimental plots was established in the springs of 1961 and 1962 on the Coulee Experimental Forest. Most of these plots showed good to excellent survivals, with a considerable advantage shown for transplants over seedlings in case of two spruce species and with red and white pines. However, south-facing, rocky, prairie soils in the area do present a problem in obtaining good initial survival.

The lowest costs per 1,000 surviving trees were achieved on stone-free sites of moderate slope, where the costs, using a heavy-duty, crank-axle Lowther machine, pulled by a light crawler tractor, were $30 for stock plus planting, using 3-0 red pine.

In contrast, the highest costs per acre occurred on steep, dry, stony, south-facing land of 53 to 55 percent slope, where the cost was $142 per thousand surviving trees for 3-0 hand-planted red pine. The lowest cost achieved here was $82 per 1,000 surviving trees, using 1-1 ponderosa pine, which showed 97 percent survival. In contrast, 3-0 red pine showed only 55 percent survival on that slope.

Available soil mositure in the surface foot of soil on north-facing slopes averaged from 2.55 to 2.75 inches of water equivalent. On the drier south-facing slopes it was only 0.75 to 1.36 inches in a comparable period.

On warm summer days the south slopes often were 4° to 6° F. warmer than north slopes, based on thermograph records in shelters at a height of 1 foot above ground. For the 11 warmest weeks the difference for all daily maxima was 2.0° F.

A table of species and age classes recommended for various aspects and cover conditions has been prepared for the reforestation effort in the Driftless Area.

- J. H. Stoeckeler

NORTHEASTERN FOREST EXPERIMENT STATION

Division of Watershed Management Research

Semi-annual Report April 1963

GENERAL

We broke even the last six months: 9 manuscripts were submitted and 9 were published--but not the same ones. A two-day session at Syracuse in March gave our watershed staff two visiting professors (Sopper and Mader), and host Prof. Satterlund, a chance to discuss some new (to us) possibilities in watershed research. Satterlund and Eschner have been doing some hard thinking on snow interception and the general role of forest-snow in hydrology of the Northeast. They're presenting some of their ideas at next month's AGU meeting. Reinhart has sent some of the Fernow data to Michigan where Bob Zahner will squeeze them into his Thornthwaite program. Pierce is contracting three more weirs at Hubbard Brook and admiring his new office. Reigner is shopping for climatic instruments.

At the Syracuse meeting: we set up a 3-day visit at Coweeta in July to swap ideas with the Coweeta staff, and we placed an order for 13 volumes of Meteorological and Geoastrophysical Abstracts for Division use. Speaking of abstracts--Sid Weitzman suggested the ARS Abstracts of recently published material on soil and water conservation as a source for watershed management reference cards. We checked and found about 100 references that could be added to the cards we sent out about a year ago. We will cut the stencils and Storey's office will run them.

FERNOW EXPERIMENTAL FOREST

A paper on the results of the Fernow commercial clearcutting is in preparation which shows that, on the Fernow, skidroad conditions and other disturbance to the forest floor have more effect on overland flow and storm discharge than does the amount of timber cut or left.

Reinhart has spent considerable time on single watershed calibration and on the application of Thornthwaite procedures to our gaged watersheds. The going has been slow but we hope that the Thornthwaite approach will be useful in the single watershed calibration. A start has been made on analyzing Fernow data using a machine program developed by Dr. Zahner at the University of Michigan.

Results of Fernow research on logging-caused erosion and on water quality were re-evaluated and presented by Lull to the Federal Inter-Agency Sedimentation Conference at Jackson, Miss., in January.

Hornbeck conducted a study of comparative rates of snowmelt (or disappearance) on the Fernow clearcut and control watersheds. Snow cover frequently completely disappeared from the south slope of the clearcutting several days before disappearance on the corresponding slope of the control. As might be expected, there appeared to be little difference in rates of melt between the north slopes of the two watersheds. Snow data will be analyzed in conjunction with records of stream discharge.

Hornbeck has also been busy on an evaluation of the accuracy of our streamgaging records; this is an outgrowth of the Watershed Research Conference at Laconia last June.

We have been occupied with putting finishing touches on a number of publications. We fervently hope that in the next period we can report that the Pierce-Reinhart paper on Streamgaging stations for research on small watersheds has finally been published.

In March, Reinhart and Hornbeck participated in the Watershed Research Conference of the Northeast Station held at Syracuse. We were reassured to find that other people have their problems too.

Writing of this report has been interrupted by highwater--2-1/2 inches of rain on ground saturated from snowmelt resulting in the highest river stages since 1954.

--Ken Reinhart

HUBBARD BROOK EXPERIMENTAL FOREST

Considerable time has been spent these past six months on non-research activities. A sizeable chunk of Accelerated Public Works money was dumped in our laps for improving our physical plant at the Hubbard Brook Experimental Forest. Although getting out plans and contracts for public works projects restricted our research production, this money will enable us in the long run to speed up our program of gaged watersheds, and improve other facilities for future research. Further non-research effort went into assistance in administering the contract for our new Office-Field Assistants Quarters.

Over the past year or so, we have dug into the why's and wherefore's of our methods of collecting and compiling streamflow records. We examined reasons for making corrections, checking work done by others, inherent errors both from instrumentation and human actions, standards of accuracy, and other associated problems. Our findings are reported in the Proceedings of the Watershed Management Research Conference on Collection and Compilation of Streamflow Records--cited elsewhere in the Northeastern Station Report. Based on these findings we revised our procedures and came up with a manual describing in detail all the steps involved in collecting, compiling and processing streamflow data from V-Notch Weirs using Stevens A-35 water level recorders. Procedures are forthcoming for the FW-1 Recorder and the Fischer-Porter analog-to-digital recorder. Copies of this manual are available on request.

New Work Plans

The effects of cutting on soil moisture and temperature in a northern hardwood stand. R. S. Pierce.

The objectives of this study are to follow the march of soil moisture and soil temperature throughout the water year and then determine the effects of two cutting levels on the regimens. Measurements will be made on three one-half acre plots (with buffer strips) using a nuclear probe for soil moisture and thermocouples for soil temperature.

The effects of cutting on some climatic variables in a northern hardwood stand. R. E. Leonard.

The objectives of this study are to determine if there are significant differences in net radiation, air temperature, relative evaporation, and wind velocity among three one-half acre plots prior to treatment, and the effects of two cutting practices on the climatic factors measured. Climatic measurements will be taken at four-foot levels in the three plots and atop a 72-foot tower.

--Bob Pierce

NEW LISBON

As the future is generally more interesting than the past, the first part of this report will deal with plans for forthcoming studies. A meeting of the Watershed Management Division at Syracuse, recently stimulated ideas toward more fundamental research in order to apply the results of our controlled watershed studies to other watersheds in the Northeast.

In the new line-project setup, Howard Lull has designated himself as a half-time assistant to the New Lisbon project. As the Pine Barrens around New Lisbon is a "natural lysimeter" (Howard's words), this project will have a part in the new approach. Lull and Reigner recently sat down and made tentative plans for several heat balance and water balance studies. We hope at least one of them will integrate with the Forest Management project here at New Lisbon. Si Little has been considering an irrigation-fertilization study, for which water balance data will be necessary and heat balance data will be either necessary or desirable.

Returning to the past, during the semi-annual period we lined the third and last weir at the Baltimore Watershed. The wooden-box weir was designed to have a vinyl-plastic lining, but the two concrete weirs both developed leaks and had to be lined. There are other possible ways to repair leaky weirs, such as American Cyanamid's AM-9. We tried bentonite in the Newark weirs with one possible success in two trials. The vinyl plastic, however, is inexpensive and we have a good background of success with it.

Individual hook gages were installed at each weir. Previously, only one hook gage was available for all three weirs at both Baltimore and Newark. The new hook gages were inspired by Willie Curtis' Technical Note 613 but were redesigned by Bill Sopper of Penn State. They are highly accurate, constructed of aluminum, and made to size for each weir. The cost was about $25 including fabrication which is a far cry from Curtis' estimate, but also a far cry from the cost of commercially-built gages.

In October Little and Reigner discussed the status of work and plans for the Dilldown Forest with several men from the Pennsylvania Department of Forests and Waters and from the Station's Upper Darby office. The Station's role in the immediate future is limited to providing, if possible, a feasible method of conversion to high forest through site preparation and seeding and to determining with State help what areas should be so treated.

On November 20 Harold Morey of the Washington Office and Frank Paradise of Region 7 met State Forester Cottrell, George Moorhead and Gordon Bamford at our office to discuss the use of prescribed fire on PL-566 watersheds with Reigner and Little.

In preparation for the Syracuse meeting, we reviewed many articles on water and energy balance studies including the

Thornthwaite and Mather publications. Previously, we had calculated monthly "actual" evapotranspiration, by the Thornthwaite method, for the Dilldown Watershed calibration analysis. Noting that there are three different ways to calculate "actual" ET by the Thornthwaite method, we ran a comparison of the three:

1. Using a mean temperature and average precipitation value for each month of the year taken from a group of years, compute an average monthly "actual" ET.

2. Using the individual monthly mean temperature and actual monthly precipitation values, calculate the "actual" ET for each month and average these values over the group of years.

3. Calculate daily "actual" ET, sum them on a monthly basis, and average the monthly values.

Using the ten years of data available from the Dilldown studies, the differences between the three methods were considerable and interesting. Comparing water deficits (potential ET minus "actual" ET), the average annual value for method 1 was only 0.17 inch; for method 2, it was 1.50 inches; and for method 3, 3.81 inches.

In method 1, those months having water surpluses are averaged with those months having water deficits. Actually, a surplus in July 1952 cannot balance a deficit in July 1953; there is no connection between the two events. But this is precisely what the first method does, and the results are very misleading.

Daily calculations take the timing of rainfall into consideration and present a far more accurate picture than the other two methods. For example, method 3 shows a deficit of 1.14 inches in August 1955. The early part of August was extremely dry, following a period of 6 weeks with practically no rain. But later in August came Hurricanes Connie and Diane with 19 inches of rainfall. Naturally, on a monthly basis (method 2) there would be no calculated water deficit--again an inaccurate picture.

--Irv Reigner

SYRACUSE

Snow Deposition and Melt

Analysis of 1961-62's snow surveys--on open land, and under brushy hardwoods, northern hardwoods, and red pine and Norway spruce plantations in the Allegheny plateau south of Syracuse--showed seasonal snow accumulations on the ground in the approximate reverse order of crown density for the sites with tree and shrub cover.

The half melt date--the date when half the seasonal accumulation of snow had disappeared--was used as an index for comparison of sites with different vegetative covers. This date was considered to be related to the prolonged high stream discharge rates during the snow melt period. It was found that half the seasonal accumulation of snow disappeared in the open and brushy hardwood sites under the cold, slow-melting conditions of late winter, before the first real spring warm spell. At the other extreme, it took approximately twenty more days of considerably higher mean temperature to dissipate half the seasonal accumulation of snow under the dense spruce stand, although this was little more than half as large an amount

Watershed Training Session

Northeastern Station watershed management research personnel and cooperators met at Syracuse March 5 and 6 to discuss some new slants in watershed research. Discussion centered around the Thornthwaite water balance procedure and the differential disposition of energy in forest stands.

Streamflow Regimen and Water Yield

Preliminary analyses of the 50 year streamflow record of a 500 square mile Adirondack watershed indicates there has been a significant 4-inch decrease in the average dormant season (October-April) runoff. The growing season (May-September) decrease in flow has been less than one inch over the same period. It is felt, these changes in flow have resulted from changes in forest composition and density, following State acquisition of most of the watershed land for a park. A careful survey of available information on the history of the forest stands on the watershed area has not been very rewarding, and the history of the stands will have to be determined by detailed field study this summer.

New Work Plan

Deposition of snow intercepted by coniferous tree crowns. A. R. Eschner and D. R. Satterlund.

Snow depth and water content will be measured on the branches of a number of small cut and mounted conifers, and periodically total amounts of snow intercepted will be determined by weighing the trees. Snow that slides, or melts and drips off the branches will be caught on a plastic sheet. Measurements will be taken on clear and overcast days, above and below freezing. Time-lapse photos will be taken.

--Art Eschner

PUBLICATIONS

Influences of forest cover on snow and frost in the Adirondacks. Howard W. Lull, and Francis M. Rushmore. Eastern Snow Conference, Proceedings of the 1961 and 1962 Annual Meeting 7: 71-79.

Management for water production on municipal watersheds. Howard W. Lull. Proceedings of the Fifth World Forestry Congress 3: 1686-1690.

Comparative influence of hardwood trees, litter, and bare area on soil-moisture regimen. Howard W. Lull and Peter W. Fletcher. University of Missouri, College of Agriculture, Agricultural Experiment Station Research Bulletin 800, 15 pp., illus.

Leaf fall, humus depth, and soil frost in a northern hardwood forest. George Hart, Raymond E. Leonard, and Robert S. Pierce. Northeastern Forest Experiment Station Research Note 131, 3 pp.

Proceedings watershed management research conference on collection and compilation of streamflow records. Watershed Staff. Northeastern Forest Experiment Station, 55 pp.

Watershed management. Chapter III. Forest land management in watershed programs. Howard W. Lull. FAO Occasional Paper No. 13, 23 pp.

Forest cutting and increased water yield. Kenneth G. Reinhart, and George R. Trimble Jr. Journal of American Water Works Association 54: 1464-1472.

Suburban hydrology can improve watershed conditions. Paul M. Felton and Howard W. Lull. Public Works 94: 93-94.

Soil-moisture depletion by a hardwood forest during drouth years. Peter W. Fletcher and Howard W. Lull. Soil Science Society of America Proceedings 27: 94-98.

Manuscripts Submitted

Some observations on precipitation measurement on forested experimental watersheds. Raymond E. Leonard and Kenneth G. Reinhart.

Efficient logging protects water quality. Kenneth G. Reinhart.

Effect of a commercial clear cutting in West Virginia on overland flow and storm runoff. Kenneth G. Reinhart.

Approximating soil-moisture storage in experimental watersheds using precipitation and streamflow records. Kenneth G. Reinhart.

Cutting the forest to increase water yield. George R. Trimble Jr., Kenneth G. Reinhart, and Henry H. Webster.

Logging and erosion on rough terrain in the East. Howard W. Lull and Kenneth G. Reinhart.

Controlling erosion from mountain logging. James W. Hornbeck and Kenneth G. Reinhart.

Variations in bulk density and moisture content within and between closely-spaced plots on Lakeland and Lakehurst sands. Irvin C. Reigner and John J. Phillips.

Snow deposition and melt under different vegetative covers in central New York. Arthur R. Eschner and Donald R. Satterlund.

PACIFIC NORTHWEST FOREST AND RANGE
EXPERIMENT STATION

Semiannual Report
Watershed Management Research

October 1, 1962 - March 31, 1963

WENATCHEE, WASHINGTON

Microclimate Studies

One of the most frequent problems in studies of the microclimate is the reduction of large quantities of analog data to some digital format. Since this problem presents itself in a forthcoming study, some time has been spent in the design and construction of a multichannel digital data system. This type of system is available commercially, but cost increases rapidly with specifications of low voltage inputs, accuracy, speed of measurement, numbers of channels, and multirange operation.

The system is similar to the Leeds & Northrup LN1000 Digital Data System with some modifications--namely timing, programming, and data format. Similar components are the balancing mechanism, encoding and translation units, and the output typewriter. Encoder positioning is accomplished with a surplus Speedomax servomechanism modified for one-second response and multirange (3) operation. Input capacity is 150 channels if desired, although present programming is 29 samples per typed line per minute. Format is 000-999 on all samples and ranges.

Since this is to be a field instrument, timing without recourse to regulated cyclic power mains is accomplished with a clockwork pulser at 5 pps. Published stability of this component is ± 1 pulse in 17 hours.

To identify time on the printed page, continuous fold 11-inch paper will be utilized. This is equivalent to 66 typed lines; 60 data lines plus one blank line per 10 minutes occupy one page, thus each minute is easily identified.

Other more rapid measurements for this study will be recorded with an oscillographic recorder or on magnetic tape.

Another aspect of this study is the requirement for high elevation shelter for this type of equipment. A used, 34-foot highway van has been modified for heat, light, and power. Moving this to the field site at 6,000 ft. will present some problems; with a semitractor ahead and a heavy-duty wrecker behind, it should present an interesting sight.

Rebuilding of a number of surplus recorders for the radiation network mentioned in the last report continues. These are Micromax units for the seven line-operated stations. Battery-operated stations (8) utilize Rustrak recorders which have been modified for range and from AC to escapement-governed DC models. All radiometers for the network have been completed although some still are to be calibrated. Installation of some of the lower elevation stations will begin in May; higher elevation stations as they become accessible.

--W. B. Fowler

Tree Root - Water Absorption

During the fall, teaching plant physiology at Oregon State University kept me pretty busy. Since then, most of the time has been spent outlining future research, writing part of the problem analysis for the Wenatchee project, purchasing equipment for the new Wenatchee laboratory and trying to obtain measurements of water absorption through suberized and unsuberized tree roots. It has proven difficult to make airtight seals around small individual roots in the pressure chamber so another method, using root potometers, is now being used for this phase of the work. Single roots, attached to intact transpiring seedlings, are enclosed in potometers fitted with a calibrated capillary tube. Water absorption by both suberized and unsuberized roots is measured simultaneously in each seedling.

--William Lopushinsky

Watershed Rehabilitation with Commercial Fertilizers

Six years after initial application, some plots fertilized in the spring of 1957 still show a 155-percent increase over controls in production of airdry vegetative material. This is down from a 210-percent increase recorded the second year after fertilization. A second area, fertilized in the fall of 1957, had a 470-percent increase in production the first year. This dropped to 125 percent 2 years later; however, these plots were on a very erosive slope, and the experiment was destroyed by soil movement from above. The following table summarizes fertilizer treatments and results:

	Area One			Area Two	
	1958	1960	1962	1958	1960
	Total Airdry Yields in Pounds Per Acre				
$N_3P_2K_2$ [1/]	1950	1450	1660	610	370
N_3	1770	1410	1400	260	295
N_2P_1	1480	1130	1270	450	375
$N_1P_1K_1$	1350	1270	1230	510	290
$N_1P_1K_1$ and wetting agent	1330	1170	1100	490	340
Control	920	1070	1070	130	305

1/ Subscript numbers are hundreds of pounds per acre of the element.

Our next step was going to involve fertilizing small (1.5 to 2.0 Ac.) eroding watersheds to see how effectively the best fertilizer treatments reduced soil particle movement. Check dams were built and soil erosion measured during a calibration period as an accumulation of soil behind the dams. While the three small watersheds are very similar in size, exposure, slope, vegetative cover, etc., they do not produce sediment in a uniform manner which will allow correlation. High variability in erosion yields is apparently caused by small things such as dams of pine needles, cones, limbs, or rocks which change position in the channels to stop or release moving soil particles. We have now proposed a technique using radioisotopes to assess rates and quantity of soil erosion and, thus, be able to measure the effectiveness of a fertilizer treatment.

In the first few growing seasons following fertilizer applications, plots were very distinct as indicated by marked increases in plant size, density, and improved plant color. Leaching of fertilizers and spreading of plant material has resulted in a block which is considerably better, but now all plots look more or less the same. Control plots, while still showing less plant production, often look as good as adjacent treated plots. As most fertilizers are readily water soluble, a trial of leaching patterns was checked by leaching spots of fluorescein dye (resorcinolphthalein sodium). This chemical is apparently very attractive to rodents as soil and all dye was removed from spots about the size of a grapefruit wherever the dye was placed.

Related studies of soils from fertilized plots have not established any significant influences of fertilization chemical soil properties other than an increase in soil organic matter. Before fertilization, organic matter averaged (average of all plots, no differences between treatments) 2.03 percent, two growing seasons later it was 2.37 percent, and in 1962 it was 3.08 percent. Higher average values were found for total soil nitrogen on plots receiving higher rates of application; however, these differences were not significant. Influences of increased soil organic matter contents on soil physical properties will be studied this spring.

The economics of application of commercial fertilizer for watershed rehabilitation seem to be justified, based on cursory calculations. Aerial application costs would vary from $1.50 to $3 per acre, depending on the size of the project. Fertilizer costs would be around $12 to $15 per acre. Even on very seriously eroding watersheds, in most cases less than 30 percent of the total area would need treatment; thus, a 300-acre watershed could be rehabilitated for around $2,000. We hope to instrument some watersheds and test the effectiveness of this theory.

--Dave Wooldridge

CORVALLIS, OREGON

General

With the end of the semiannual report period we are losing Ned Bethlahmy to the Intermountain Station. He will be WMR project leader at Boise. Norm Miner, who has been working on his doctorate at the University of Washington, returned to the Station to keep the Bull Run Study going. The overlap of 2 months provided an excellent opportunity for Norm to pick up the thread of Ned's work.

Dyrness and Rothacher have gone through the processes necessary to prepare several problem analyses. The Corvallis Project has settled on three major problems.

1. Regulation of streamflow from forests of the rainfall zone to control floods and increase low flows.

2. Analysis of problems of water quality in forested areas of western Oregon and Washington.

3. Prevention of accelerated soil movement and rehabilitation of depleted sites.

The major portion of our studies are still concentrated at the H. J. Andrews Experimental Forest and on the Bull Run watersheds. To facilitate work at the Andrews and elsewhere, we are planning to modify a trailer for badly needed laboratory space. Some time ago there was a report describing a trailer equipped as a laboratory, but it has since been lost in our files. We would appreciate learning of any experience others have had in outfitting a semiportable laboratory.

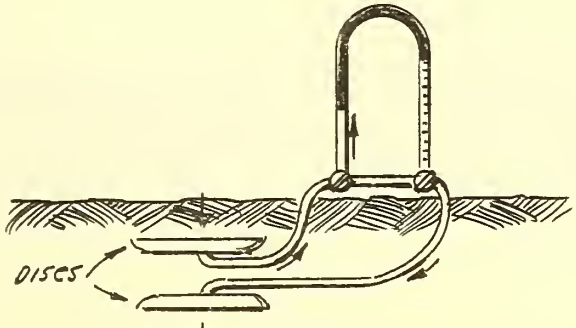
Miscellaneous Observations

During the past 6 months, western Oregon has been subjected to two extreme weather events. On Columbus Day strong winds wreaked havoc in many costal areas, especially just to the west of Corvallis. And again, as January merged into February, we were blanketed with snow and heavy freezing rain. Branches, trees, and uproots have accumulated in numerous jams in many streams. During a recent period of heavy rains, the creek that flows by the house of one watershed researcher (everyone in watershed management research should have his own creek) was observed to be excessively muddy. A quick survey revealed that almost without exception, the small side tributaries were flowing relatively clear, but the main stream, choked with wind and ice storm debris, was very muddy. It was evident that the creek was busily digging new channels around the debris and producing a heavy sediment load in the process. Apparently natural events such as these may occasionally create as much disturbance to stream channels as some of man's activities.

--Jack Rothacher

Flow of Water Thru Saturated Soils

More experience has been gained with the saturated flow instrument described in the April-September 1961 Semiannual Report. Though testing of the instrument is not complete, our experience with it may be useful to others originating saturated flow studies. The apparatus, in its simplest form, consists of two RA-84 alundum porous discs assembled as described by Tanner (Proc. Soil Sci. Soc. Am. 2: 55-64). Both discs are interconnected, as shown in the following figure, through a displacement flow meter.



The system must be airtight since water is syphoned from the upper to the lower disc when the meter is elevated above the discs. When in operation, the flow meter "U" tube remains in a horizontal position. Water passes through a shunt at all times except when measurements are taken. Timed readings are taken by diverting the path of flow through the meter, thereby displacing the immiscible fluid (xylene with iodine dye). The volume displaced is read directly on a graduated tube which forms one arm of the meter.

The difference in elevation between the disc surfaces is the driving force (head) which moves water through the instrument. Conductivity of the instrument must be known so that discs are installed with sufficient head to sample the expected range of flow rates. New discs were found to be several times more conductive than discs which had been installed in a soil profile previous to testing. Evidently the pores became partially occluded with soil fines. Maximum flow rate through the instrument is expressed by the following equations in which "y" is the flow rate in inches per hour and "x" is distance between disc surfaces in inches.

new discs	$y = -.43 + .33x$
used discs	$y = -.10 + .07x$

One test installation was made near the surface of a well-drained soil profile. The top disc was placed 2 inches below the soil surface in the "A" horizon. The plate surfaces were 4 inches apart. During a rain shower in February 1962, 0.18 inch of rain fell in 3-1/2 hours. Flow rate followed precipitation rate very closely, but was delayed at the peak by 1 hour from the time of peak rainfall intensity. Total flow and precipitation were nearly equal during the storm.

Before the instrument can be used in a study of saturated flow, we must know how variable flow may be at any one depth in a soil profile. Five pairs of discs are presently being installed for this purpose.

R. L. Fredriksen

Small Watershed Studies - H. J. Andrews

Wyssen Skyline Crane.--In the last semiannual report we presented a highly optimistic report on the Wyssen Skyline Crane currently being used to yard logs from our 237-acre watershed 1. On the test strip where favorable topography prevailed, the 10-ton (W-200) skyline crane did very well. Now, on the second line in the much more difficult topography of watershed 1, a number of problems

have arisen. Breakdowns have been more frequent, production has been low, and rig-up costs have been unusually high. This emphasizes the fact that this machine, like all others, has its limitations. Perhaps one of the most important factors is the need to plan the layout of the cutting area to provide the required slope to the skyline with a minimum number of intermediate support trees.

At this date the timber on a little less than half of the watershed has been felled and about one-quarter of this has been removed. Some preliminary results should be available in the coming months. From all observations to date, soil disturbance has been minor.

High-lead logging.--The three planned clear-cut units on watershed 3 (250 acres) have now been logged, but not burned. We are anxiously looking forward to learning what changes in streamflow will result from clear cutting 25 percent of the watershed. The operator did a good job of logging. Soil disturbance does not appear to be excessive. We wonder how you keep an operator from doing a better than average job in an experimental watershed? As chance would have it, the past winter has as yet produced no major storm, although we have experienced some moderately high flows.

--Jack Rothacher

Soil Variation

We are continually impressed by the fact that we know so little about the soils on the experimental watersheds in the H. J. Andrews Forest. Despite two separate soil surveys in the area, about the only thing we know is that the soil pattern is extremely complex. It is becoming abundantly clear that we need a much more intensive inventory of the soils which are present if we are to gain the maximum amount of information from these watersheds. For this reason, we are planning to conduct a very thorough soil survey of the experimental watersheds this summer. We will attempt to design our soil mapping units in such a way as to keep soil characteristics within delineations as uniform as possible. In addition, we plan on characterizing the variations within mapping units, as well as the modal characteristics.

At the present time, we are still undecided which types of field and laboratory characterization will be the most valuable. We probably will run all the standard chemical and physical analyses on the principal soils. Where we really are stumped is in the field of soil hydrologic properties. We want to get as much of this information as possible to aid in hydrograph analysis.

We would appreciate any suggestions concerning field and laboratory tests which would aid us in characterizing the hydrologic properties of these soils.

--C. T. Dyrness

Automatic Data Processing

Just before leaving, Ned Bethlahmy, working with the Station statistical section, worked out the last bugs (we hope) in our automatic data processing program for handling streamflow data. Besides the usual summary of flow by interval, day, and month, we will have summaries of flow by cfs classes for rising and falling portions of the hydrograph. We expect our program to help us materially in analysis of streamflow. Ned has prepared a report on the program which should be out soon.

--Jack Rothacher

Comments on "Fire and Water"

Having just returned from a 4-year ivory tower leave, I read Ashley Schiff's book with the idea that it might help us do a more effective research job.

Last fall I heard him speak at the Western Forestry and Conservation Association meeting in Seattle. Looking at forestry from outside the profession, he sees us approaching the same fate that befell Public Administration as a discipline -- becoming inbred. He accused us of not making use of information from other professions. During his speech he antagonized at least one-half of the audience by his choice of words and manner of speaking, and I'm sure they didn't benefit from his thesis. After looking at his book, I felt that this same thing might happen to the reader. If one stops reading before the last two pages, he would be left with an entirely false impression. Schiff concludes that at the present stage of maturity of the forestry profession (i.e., out of the crusading for protection phase and into the active management phase) the present organization is the best for obtaining productive results and expediting application. I think we should keep in mind that the problems he mentions will continue to be present and studies that attempt to correct mistakes in management will not be as productive as studies that aim at preventing mistakes.

--Norman H. Miner

SEMIANNUAL REPORT

Pacific Southwest Forest and Range Experiment Station

October 1962 through March 1963

WATER SOURCE HYDROLOGY

Soil Erodibility at High Elevations

A 7090 multiple regression analysis has just been completed for the Teakettle Experimental Forest soil erodibility study. Two hundred and eight surface soil samples were related to rock type, cover type, aspect, elevation and slope. The dependent variables consisted of soil textural classes, organic matter, Middleton's dispersion ratio and Anderson's surface-aggregation ratio.

Preliminary results show that soils developed from olivine basalt were less erodible than soils developed from quartzite and granodiorite. Fir soils were less erodible than those under pine, brush and grass cover types. The erodibility position of the latter type is opposite from results of prior studies, but at these elevations (6500-8000') the grass is exceedingly sparse and is not ecologically well established. The east aspects tended to be less erodible than the north, south and west aspects. However, the significant tests are somewhat low.

Texture variables were significantly related to both elevation and slope in that particles larger than sand size and total clay decreased with elevation while sand had a corresponding increase. Sand did not correlate with slope but particles larger than sand and total clay decreased with an increase in slope from 20 to 40 percent. Erodibility did not change significantly with elevation or slope in these ranges. Organic matter increased with elevation but was not related to slope changes.

Erodibility tests showed that these soils were approximately 2.7 times more erodible than soils formed on similar rock types at lower elevations, and they may be subject to severe gully erosion if subsequent treatment impact is not carefully controlled.

Donald W. Willen

Climate and Soil Erodibility

The relation of development of erodible soils to climate is of most interest to the soil morphologist and certainly of some interest to the sedimentationist. Some schools of soil morphologists would have

us believe the climate was the sole control of soil development. At least for the young, residual soils of the Pacific Coast mountains, recent studies have indicated that the rock type is the dominant influence.

But climate is important. Early studies showed differences in soil erodibility with crude climatic segregations--elevation and geographic zone (Andre and Anderson 1961). More recent studies (Wallis and Willen 1962) have shown that an expression of the climatic factor can be made from the amounts and temperature of the percolating rainfall. The dispersion ratio is related to the dissociation constant of water (Equation 1); the surface-aggregation ratio of the soil is related to the amount of precipitation, the dissociation constant of water for that precipitation and their joint product (Equation 2).

(1) Log DR =	5.7	Dispersion Ratio
	+ 1.6 Kw	Dissociation constant of water (summed for 12 monthly values of $Kw = 0.2681(1.048^F)$, where F is mean monthly temperature in degrees Fahrenheit.
	- 0.014 Kw^2	Square of previously defined variable.
(2) Log S/A =	319	Surface-Aggregation Ratio
	- 6.39 P	Average annual precipitation, inches.
	- 7.52 Kw	(Same as in Equation 1).
	+ 2.42 KwP	Summation of twelve monthly products of Kw and P.
	+ 0.0404 $(P)^2$	Square of previously defined variable.
	+ 0.0553 Kw^2	Square of previously defined variable.
	- 0.00693 $(KwP)^2$	Square of previously defined variable.

James R. Wallis and
Donald W. Willen

Watershed Drainage Pattern Analysis

Horton's quantitative methods of describing topography have been the basis of much fruitful research effort. His laws of drainage composition

minimized the need for actual values of stream order in topographic analysis.

Justifiable modifications of Horton's original stream ordering concept were made, particularly by Strahler. Some geomorphologists have doubted the validity of Horton's laws of average lengths and average slopes when Strahler's numbering was used. Finally Broscoe tentatively introduced procedures which made these laws and Strahler's ordering system compatible by defining mean length as the cumulative mean segment length (L'):

$$L' = \sum_{u=1}^{n} \bar{L}_u$$

and mean slope as cumulative mean segment slope (H'/L'):

$$H'/L' = \sum_{u=1}^{n} \bar{H}_u \Big/ \sum_{u=1}^{n} \bar{L}_u$$

where u is the segment order, $\bar{H}u$ and $\bar{L}u$ are respectively the mean elevation difference and mean length observed for Strahler segments of order u, and n is the order under investigation.

Independently, we developed procedures identical to Broscoe's and applied them to sixty northern California streams. Our data confirmed the law of average length based upon L' without any deviations. Forty watersheds conformed to the law of average slopes based upon H'/L' while twenty did not form the desired exponential function. However, in every case a smooth curve could be drawn through each of the sixty plots. The deviations from linearity can usually be explained by geologic or climatic influences.

Kenneth L. Bowden and
James R. Wallis

Soil Influences on Evapotranspiration

Basic studies are being initiated to determine the influence of soil physical properties on the hydrologic process of evapotranspiration. Soil properties which are known to influence the rate of saturated and unsaturated flow in soils are being investigated to assess their relative influence on both the rate and amount of soil moisture depletion. Methods for determining capillary conductivity of soils in the disturbed state will hopefully be extended to characterize this phenomena in the undisturbed field condition. Isolation and

characterization of these rate determining processes should aid in formulating more suitable prediction models for soil moisture depletion, particularly under arid conditions where readily available water for evapotranspiration is limited. Variables such as volume and energetics of water during depletion, rate of growth and distribution of plant roots in response to varied moisture conditions, porosity of the soil, and moisture transmission properties of soils will be incorporated, along with meteorological phenomena, into a soil moisture depletion model for arid, wildland areas. Preliminary experiments are being carried out on soil samples collected at the Central Sierra Snow Laboratory to assess the influence of physical properties of the soils on soil moisture losses.

Leonard F. DeBano

SNOW ZONE MANAGEMENT

More on Radioactive Sources in Measuring Snow

Snow density (determined gravimetrically) ranged from 12 to 60 percent. Usable regressions of snow density (D) with neutron counts (Cn) and gamma counts minus 5,000 (Cg) in CPM had been reported previously. Improvements in the regressions were obtained by using the counts above and below as well as at the measurement depth. Counts 6 inches above (Cna or Cga) and 6 inches below (Cnb or Cgb) as well as the counts at the point were used. For gamma probe at depths $\geq$ 18 inches, $D = 11.8 + 0.022\ Cg^2 - 0.722\ (Cga - Cg) - 1.03\ (Cgb - Cg)$; for depths of 12 inches, $D = -2.7 + 1.25\ Cg + 0.50\ (Cgb - Cg)$; and for depth of 6 inches, $D = -2.6 + 1.33\ Cg + 1.39\ (Cgb - Cg)$. Standard errors of estimates were 3.5, 2.3, and 3.4 percent. For the neutron probes at depth $\geq$ 12 inches, $D = 9.1 + 6.25\ Cn - 0.052\ Cn^2$; and for depth of 6 inches, $D = 2.2 + 12.3\ Cn - 1.00\ Cn^2 + 2.9\ (Cna - Cn) + 11.2\ (Cnb - Cn)$. Standard errors of estimates were 3.6 and 2.2 percent. Counts in water for these probes, with aluminum access tubes were 15,900 and 44,400 CPM for the neutron and gamma probes, respectively.

Can the probes help detect the time when the spring snowpack will start to melt and predict the rate of melt? Some preliminary tests indicate this is a distinct possibility. The rate of melt of spring snowpacks has been found to vary widely from year to year, even when the melt is expressed in terms of the amount of heat rather than time alone. The problem may be expressed as: how many degree days will be required before the melt of the pack starts and at what rate does the pack melt per unit of degree day after the start? By comparing three conditions which had widely different snowpack characteristics early in the spring (April 3-7, 1962), the lag in the initiation of melt and

the rate of melt in those three conditions were found to be related to the neutron and gamma count profiles in the snowpack (Table 1).

Table 1.--Spring snowmelt at three sites as related to neutron and gamma counts at the top and bottom of the snowpack, Central Sierra Snow Laboratory, elevation 7500', 1962

Condition	Neutron counts		Gamma counts		Lag in melt	Melt rate
	Top	Bottom[1/]	Top	Bottom[1/]		
	1,000 CPM				Degree days	In./degree day
Open	5.2	6.0	39	43	60	0.15
Shaded	3.5	6.0	35	43	90	0.11
Forest	3.5	5.8	35	43	130	0.10

1/ One foot from top and bottom of snowpack.

Note that the bottoms of the snowpacks were remarkably uniform for both gamma and neutron counts. However, the top of the snowpack shows fewer counts near the surface and widely different counts among the three conditions. It is generally recognized that melt of a snowpack is mostly from the surface. The counts in the surface snow appear to be related to the delay in start of the snowpack melt and to the rate of melt of the pack after melt starts. This possibility of the gamma and neutron counts permitting prediction of snowmelt's contribution to streamflow deserves further exploring.

Henry W. Anderson and
Philip M. McDonald

Restoring Depleted Sites

A study has been initiated at the Central Sierra Snow Laboratory at Soda Springs, aimed at developing methods and techniques for restoring depleted high elevation snow zone watersheds. Through accidents of fire, climate, and misuse of the land by man and his animals, the resulting loss of soil and site quality has seriously impaired hydrologic control of runoff and erosion in these depleted and often actively deteriorating areas.

Preliminary results on one such depleted area have shown a wide variation in the soil profile and in particular, a wide range of soil texture and placement and extent of semi-hardpan layers within it. As expected, soil density determinations with a radioactive soil density probe have also shown a relatively wide range of density values. Maximum soil moisture depletion values, as measured with a neutron probe, showed a surprisingly large amount of soil moisture retained in the profile, particularly below the 18 inch depth. This is undoubtedly the result of large, bare areas which, due to their dusty surface condition, effectively reduce evapotranspiration from the soil.

Following a major late fall storm of 16.4 inches of precipitation, soil moisture (percent by volume) increased 7 to 40 percent from maximum depletion, with the average increase being 30 percent. This indicates a large moisture detention in the soil in spite of the depleted condition of the area. These preliminary results are encouraging in that they indicate favorable conditions are present on which restoration may proceed more rapidly than hitherto thought.

Future work will be aimed at establishing vegetation on the area. This vegetation ideally would use a minimal amount of water itself and also be able to occupy the site and effectively reduce erosion and runoff. Further tests will show the best method of vegetation establishment and the effect of fertilizer and grazing on the soil, vegetation and hydrologic development of the area.

Philip M. McDonald

Logging Effects on Soil Moisture

Trends of summer soil moisture loss from logged forest openings and from the unlogged forest surrounding these openings were studied in the sub-alpine forest zone of the Sierra Nevada west side near the Central Sierra Snow Laboratory. Soil moisture depletion was measured in forest openings which were created by logging in 1959, 1955, 1950, and 1948, and in the forest surrounding these openings. As a result of two-years' data, the following conclusions may be drawn:

1. Seasonal Trend of Soil Moisture Depletion. Soil moisture was observed to be uniformly near field capacity throughout all plots early in the depletion season, in early June, except in areas where spring snowmelt was delayed. As the summer season progressed, soil moisture was lost most rapidly from the forested portions of the plots and at progressively slower rates toward the center of the openings. The rate of moisture loss was greatest early in the summer and decreased as the season progressed and the availability of moisture decreased. Maximum soil moisture depletion occurred in early September with nearly all the available moisture being depleted from

the forest. The quantity of residual soil moisture increased toward the center of the openings.

2. Relation of Opening Age to the Seasonal Trend of Soil Moisture Depletion. The loss of moisture from logged openings increases with the age of the opening. Moisture loss in the recent openings is limited to surface evaporation from bare soil. As reproduction becomes established in the older openings, moisture loss then becomes limited to the distribution of roots throughout the soil profile and to the availability of water in the soil.

3. Relation of Opening Age to Soil Moisture Distribution at Maximum Depletion. The primary change in moisture depletion in the first five years since logging was probably due to the extension of roots of the surrounding forest into the opening. Ten years after logging the effect of new vegetation has become apparent and the effect of the roots of the surrounding forest has become static. Twelve years after logging the new vegetation in the opening has nearly fully utilized all available soil moisture from the opening except at the lowest depths and moisture loss within the opening has essentially returned to the uncut condition.

4. Relation of Opening Age to Summer Moisture Savings at Maximum Depletion. A regression was fit to the values of seasonal soil moisture savings in inches (Y), plotted against the logarithm of the age of the opening in years (t). Seasonal soil moisture savings is the difference between soil moisture losses in the forest and in the opening at maximum depletion. This regression is defined by the line:

$$Y = 6.9 - 5.73 \log t$$

The regression indicates seasonal soil moisture savings will become zero approximately 16 years after cutting. A total savings of 34 inches is indicated within the opening as a result of logging for the 16 year period.

The summer soil moisture regime is only a portion of the area water balance. An understanding of the effect of logging upon interception, infiltration and evapotranspiration during the rest of the year would be required to complete the balance. The study has indicated the effects of logging on the major component of water loss and on the duration of the logging effects on that loss.

Robert R. Ziemer

More on Hexadeconol Effects on Summer Water Losses

First year results were summarized in a previous Semiannual Report. Those are compared with second year results and summarized here.

Reduction in evapotranspiration for each summer period was taken as the difference in soil moisture storage at maximum depletion between the test and a control site, adjusted for differences between the two sites in the years before treatment. Reductions in evapotranspiration differed between the natural site type, between the first and second year after treatment, and between methods of applying the hexadecanol.

Red-fir forests, with one exception, showed essentially no difference between treated and untreated sites the first year after treatment--both when hexadecanol was applied to the soil and flushed in with water and when applied to a deep snowpack and allowed to percolate with the melting snow water. The second year after application on soil, we found a consistent decrease in the soil moisture storage at maximum depletion ranging from 0.2 to 0.6 inches less water than in the control sites.

The exception to the general lack of effects of hexadecanol on summer evapotranspiration on red-fir sites was found at site No. 92. A heavy treatment (680 pounds per acre) was applied with an average saving of 1.5 inches. Part of the site was bare of snow, so that hexadecanol was applied to the soil and 6 inches of snow shovelled on top. At these places, a large reduction in loss occurred--3 1/2 inches for the 3-foot soil depth in the summer of 1962. At other points where hexadecanol was applied to deep snow, at the same site, the saving was only 0.7 inches. Lesser rates of application of hexadecanol under similar circumstances failed to show appreciable effects.

Brushland sites which had been bulldozed in 1957 behaved differently than natural brush sites when treated with hexadecanol. The bulldozed brush sites, which had been planted to small pine trees and brush was becoming re-established, showed a large difference in water loss the first year after treatment--2.0 inches associated with an application of 135 pounds per acre of hexadecanol in mid-summer. The second year after this application, a reduction in evapotranspiration of only 0.5 inches was indicated for a 4-foot soil. In a natural brush site, very little effect was observed from an application of 35 pounds per acre of hexadecanol. With the 135 pounds per acre application on natural brush, an 0.5 increase in loss the first year was indicated and an 0.5 decrease occurred the second year. Deeper soils showed a similar deficit in soil moisture in the first year, but a larger reduction in loss the second year--1.8 inches instead of 0.5 inches.

Bare soil and herbaceous Wyethia sites showed essentially negligible reductions in evapotranspiration associated with hexadecanol applications. Reductions the first year ranged from -0.1 to 0.3 inches. The second year results indicate small but consistent negative effects ranging from -0.1 to -0.3 inches. These values are, however, approaching our accuracy of measurement of total summer water loss.

Henry W. Anderson and
Robert R. Ziemer

Effects of Hexadecanol on Snow Evaporation

The use of hexadecanol as a snow evaporation suppressant looks very promising. After spraying the emulsion form of hexadecanol on the snow, at a rate of 10-15 pounds per acre, evaporation reductions ranging from 13 to 90 percent were experienced. We tested the effectiveness of hexadecanol under forest stands of various densities and different sized forest openings. The interesting things we found were that the greatest reductions were in areas where the evaporation was the greatest--large, open areas and ridge tops. The hexadecanol was least effective under the dense forest cover.

We are now in the process of finding out how frequently applications on the snow need to be made and whether or not the rate of application should differ for varied forest conditions.

Allan J. West

LOWER CONIFER ZONE

Watershed research here at the PSW Station was strengthened last fall by the arrival of Robert A. Muller, fresh from Syracuse University where some of you may have become acquainted with him. This is Bob's first contact with the West and western forests and snow. At Syracuse, Bob's M. A. thesis was on the lake-effect snow squalls of up-state New York. His doctoral thesis was a study of changes in the yield of streams of the Allegheny Plateau following abandonment of farmland and its reforestation from the 1930's on. The techniques developed in these studies should be very useful in some aspects of our program. Since his arrival, Bob has been primarily concerned with a study of the radiation balance under different forest conditions which is now in the advanced planning stage.

Eugene Kojan, an engineering geologist, has joined our group to work on some of the geologic problems of our lower elevation watersheds. Gene has had field experience in the Northeast, Central America, and here on the West Coast. He has done graduate work at

Harvard, University of Washington, and at Berkeley. Gene will be concerned primarily with studies of the mass movement of soil and fractured rock which may be major sources of sediment in much of the Lower Conifer Zone. He hopes to develop some data which will indicate the magnitude of mass movement in certain areas, and to study the effects of certain physical characteristics of the soil and rock, climate, and vegetation on these phenomena. Gene would be glad to hear from any of you who are interested in this problem or may have some observations and ideas to pass on.

Caspar Creek Study

Our cooperative study (Forest Service, California Division of Forestry, California Department of Fish and Game, and California Department of Water Resources) of the effects of logging operations on streamflow, sedimentation, and salmon and steelhead populations in the redwood-Douglas-fir area has taken a full step into the watershed calibration stage. Concrete was poured in October (as luck would have it, the first major storm of the year arrived the day scheduled for pouring, but somehow the forms were saved) and the gaging stations went into operation at the beginning of November. Clark Gleason and the State forestry people have had the normal set of problems with a new gaging station but are getting these straightened out. The stations have combined V-notch and Cipoletti weirs with splash dams and fish ladders below which have caused some difficulty. The splash dams have tended to cause submergence of the weirs during high flows. The Fish and Game people are currently working out changes which should correct this.

Robert P. Crouse

Some Problems of Radiation Measurement

Recent preparations for studies of forest radiation in the Lower Conifer project of the PSW Station have resulted in some experience that may interest others working on questions of forest climate in which one or several of the radiation fluxes play important roles. Since the individual fluxes are differently modified by vegetation and differently received by it, we are concerned with their separate measurement and also with calculating their sums and differences as measures of energy input. The diagram following, developed in teaching radiation, is one way to visualize these fluxes and the derived values.

	Direct solar rad. to 3 u	Diffused solar rad. to 3 u	Long-wave radiation 3 to 50 u	"All-wave" radiation 0 to 50 u
Downward onto a horiz. surface	1 S'	2 D	9 G	13
Upward from a horiz. surface	3	4	10 A	14
Sum	5	6	11	15
Net difference	7	8	12	16

Cell 1: direct solar radiation onto a horizontal surface, (S' = S sin h, where S is the direct solar flux on a normal surface, and h is the angular elevation of the sun).

Cell 2: diffused or scattered solar radiation on a horizontal surface, D; includes sky radiation and that diffused by clouds.

Cells 3 and 4: the reflected upward fluxes of 1 and 2, respectively. Many types of cover of the earth's surface have different albedos for direct and diffused solar radiation.

(In much meteorological work, cells 1 and 2 are measured together, as "insolation" or "global radiation," as are cells 3 and 4, but biological needs are different.)

Cells 5 and 6: sums, without regard to sign, of the values above them; they indicate total heat load on, for example, both sides of a horizontal leaf, as in Gates' investigations.

Cells 7 and 8: differences of the two top cells; they indicate net absorption of short-wave radiation by the surface of the earth.

Cell 9: downward "long-wave" radiation from gases and clouds in the atmosphere, variously called atmospheric radiation, counter-radiation, or Gegenstrahlung, G.

Cell 10: upward long-wave radiation emitted by the surface of the earth or vegetation, as a function of surface temperature and emissivity. It includes a small amount of reflection of the downward long-wave flux. Ausstrahlung, A.

Cell 11: the sum of the two long-wave fluxes, without regard to sign.

Cell 12: the difference of the two long-wave fluxes representing net loss of heat by long-wave radiation at the earth's surface, as observed, for example, at night.

Cell 13: the sum of all three downward fluxes of radiation, sometimes called "all-wave" in lieu of any better term, to indicate that both short-wave and long-wave radiation are measured.

Cell 14: the corresponding sum of all three upward fluxes.

Cell 15: the sum of cells 13 and 14. It is also the sum of cells 5, 6, and 11.

Cell 16: the difference between cells 13 and 14, and hence the net all-wave radiation budget at the earth's surface. It is commonly measured and has great climatic significance, but without information on component fluxes is difficult to interpret, particularly in vegetation environments. It is also the algebraic sum of cells 7, 8, and 12; sometimes called "net radiation" or the "radiation balance."

In the following diagram are shown observations made at 1024 hours, August 29, 1962, at the Central Sierra Snow Laboratory radiation site (in langleys per hour):

	Short-wave direct	Short-wave diffuse	Long-wave	All-wave
Downward	1	2	9	13
	+75			+85
Upward	3	4	10	14
Sum	5	6	11	15
Difference	7	8	12	16
				+35

Direct and diffuse short-wave radiation were not measured separately; the combined values (in cells 1 and 2) are the average of readings of four Eppley and Kipp sensors which were in fair agreement. In cell 13 is the reading of Gier-Dunkle hemispherical all-wave radiometer; in cell 16, that of one of two Gier-Dunkle net radiometers (the other read 43).

Now, if we estimate reflected short-wave radiation (cells 3 and 4), partly from albedo measurements made at this site during the Engineers' snow program, partly from knowledge of subsequent changes in its surface, and if by subtraction we calculate the fluxes in cells 9 and 14, the diagram begins to fill in:

1 2 +75		9 +10	13 +85
3 4 -8		10	14 -50
5	6	11	15
7	8	12	16 +35

The rest of the calculations follow rapidly:

1 2 +75		9 +10	13 +85
3 4 -8		10 -42	14 -50
5 6 83		11 52	15 135
7 8 +67		12 -32	16 +35

The diagram looks nice, but there is a question whether it reproduces the field situation. One may wonder, for example, at the downward long-wave radiation (cell 9) which, according to the few reported measurements, is seldom this small (except at the South Pole where it was measured as about 7); mid-latitude stations rarely report less than 25 ly/hr. Again, a reader might question the upward long-wave radiation (cell 10) if he knew that the air temperature was 17 deg. C and the rock and soil probably not more than 20 deg. (from a 20-deg. surface, upward long-wave radiation would be 36 ly/hr).

This set of measurements was not taken for the analysis it has just received, but these questions suggest that when we run such a set-up we should measure at least four fluxes so as to avoid having to estimate, say, albedo. Preferably, we should measure five or six fluxes so as to provide means of internal checking. As they stand, these data do not tell us anything clearly about radiation in nature, with or without forest, but they do warn us to take care in using instruments that in general are not standardized, and tell us that, where we can, we should replicate instruments.

Speaking of replication brings us to the second experience. During the fall of 1962, several short-wave sensors were delivered for transmission studies. A chance finally came to run them against each other in cloud-free and smog-free air, and eleven sensors were set out, gleaming in the sun, none bearing more authority than any other. Fortunately, we had also a more precise instrument (called a sub-standard, merely because it is below the Smithsonian standards which have now been integrated into an international scale). The cost of this sub-standard was justified when it turned out that the sensors, unexpectedly, exhibited considerable disagreement among themselves; we should not have known which one to believe. At 60 ly/hr intensity, differences range from plus 4 to minus 7 percent. We are now convinced of the correctness of the published experience of many others, that even the best radiation sensors need frequent checking.

Measurement of even short-wave radiation, for which sensors have usually been well regarded, and particularly of long-wave or all-wave radiation, for which there are no standard sensors, is clearly full of problems of a peculiarly frustrating kind. While the 16-cell diagram presented earlier, useful in teaching, provides a gross check for consistency and points out meteorological impossibilities, it goes no further. Comparing measurements with those of other investigators (one of us has compiled observational data on typical values and regimes of nine radiation fluxes) also calls attention to improbable values. While these indirect checks are useful for a while, we really need ways of directly checking each sensor and would

welcome anyone's ideas on calibration, ways to do it for long-wave, ways to facilitate it, and ways of making it more reliable.

C. W. Mansfield, R. A. Muller
and D. H. Miller

SAN DIMAS EXPERIMENTAL FOREST

Effectiveness of Erosion Control Measures

As one of the speakers said at the last A.G.U. meeting: "due to the delays that customarily result from using high speed electronic data processing systems, these results are more than a year old." The data reported here are for the same storms that Bob Crouse discussed in the Semiannual Report a year ago.

The peak flow estimates are now based on model studies conducted last summer. Debris production was computed using an IBM 1620 computer program which uses field data obtained by measuring depths beneath a steel tape stretched across several parallel profiles.

Table 1.--Highest flood peaks observed during Hydrologic Year 1962

Broadcast sowing treatments	Mechanical treatments				
	No mechanical treatment	Contour trenches	Channel stabilization	Side slope stabilization	Mean response
No Broadcast Seeding	2.1	1.7	1.2	3.8	2.2
Low Density Annual Grass	6.0	1.6	2.8	1.1	2.9
High Density Annual Grass	2.5	1.4	3.3	1.8	2.2
Low Density Perennial Grass	3.6	7.4	7.7	2.5	5.3
High Density Perennial Grass	3.9	0.7	3.0	1.8	2.4
Mean Response	3.6	2.6	3.6	2.2	3.0

Table 2.--Total debris production during Hydrologic Year 1962

Broadcast sowing treatments	Mechanical treatments				
	No mechanical treatment	Contour trenches	Channel stabilization	Side slope stabilization	Mean response[1/]
No Broadcast Seeding	29.0	16.7	13.8	9.9	17.4
Low Density Annual Grass	39.7	1.8	25.4	5.8	18.2
High Density Annual Grass	31.4	6.7	8.4	9.1	13.9
Low Density Perennial Grass	35.6	26.6	26.4	8.6	24.3
High Density Perennial Grass	26.0	6.9	23.3	8.7	16.2
Mean Response[2/]	32.3	11.7	19.5	8.4	18.0

1/ Row effects significant at the .41 level
2/ Column effects significant at the .05 level

When interpreting the results in Tables 1 and 2, you shouldn't look too closely at row x column effects. We tried to assign the treatments so that the inherent erodibility of the watersheds was averaged out over each row or column. There is no replication within a cell, however, so it reflects row x column x watershed interactions.

The only new thing to report about treatment effects on flood peaks is that apparently the poor catch of grass in watersheds sown to low density perennials couldn't compensate for the loss of native broad leaves due to the accompanying herbicidal spraying. As a result the row mean for the watersheds with low density perennials as one of their two treatments gives the highest debris production and flood peaks.

The reduction in debris associated with the high density sowings (compare row means for no seeding and those treatments end) is comforting but of questionable validity. There was an average of only 9.9 percent ground cover due to treatment in the high density annual

grass watersheds and 2.9 percent in the high density perennial watersheds at the end of the season and only about one-fourth this amount during the first two storms.

The relatively poor showing (40 percent reduction in debris vs. 79 percent for side slope stabilization and 64 percent for contour trenches) of channel stabilization in controlling erosion may be the result of the size of our watersheds. When the dams filled with debris the channel length and roughness was considerably reduced. This possibly resulted in shorter concentration times[1/], higher peaks, higher velocities and consequently relatively greater ability to transport sediment washed from the side slopes. In large watersheds, I wouldn't expect this effect to be so pronounced. Our results are about in line with the claimed effectiveness of the channel stabilization treatment.

Raymond M. Rice

Another Look at Wetting Agents

In the October 1961 - March 1962 report, we stated that wetting agents might reduce surface runoff and erosion from burned watersheds. It appeared to us then, that our non-wettability of the surface soil was due to an ash dust layer left on the surface following fires. Our cooperators at UCLA intimated that there was a further problem in wettability of the soils brought about by leaching of the chaparral litter. Both of these wettability problems do exist in our watersheds.

During the fall of 1962, in cooperation with UCLA, we established six plots on a recent burn to evaluate a wetting agent[2/] as a possible erosion control treatment. The soils on the plots are non-wettable. There is no apparent variation between plots. Plot slopes average about 60 percent.

The chemical is a non-ionic compound and was sprayed on the plots at a dilution of one part active ingredient to 3600 parts water.

We are measuring total debris yield in catchment troughs and will continue collecting data from these plots to determine the longevity of the treatment.

1/ A "t" test does not support this hypothesis.

2/ Supplied by Process Chemical Company of Santa Fe Springs, California.

To date, we have had only four storms that produced a measurable amount of debris. The figures for debris production appear in Table 3. The wetting agent would appear to be a promising treatment for reducing debris movement from recently burned watersheds with non-wettable soils.

Table 3.--Total debris (cubic feet) by storm

Storm Amt. (inches)	Plots					
	1 2/	2 2/	3	4 2/	5	6
1.29	.01	.05	.43	.01	2.01	3.01
.98	.09	.06	.09	.07	.02	.12
6.16	.001	.49	1.20	.004	3.60	5.40
1.32	Trace	.15	.19	.04	.35	.64

2/ Treated plots.

Jay S. Krammes

WATERSHED MANAGEMENT RESEARCH, HAWAII

Kaukonahua Watershed Studies

Between 1951 and 1955 the Hawaii Forestry Division collected rainfall and streamflow data from two small watersheds on Oahu. One watershed was covered primarily by uluhe fern and the other by planted trees. We are analyzing the data in a study of rainfall-runoff relations. Average runoff for the tree-covered watershed was only 1 inch per year during the study period. Year-to-year variation in runoff from these small watersheds is quite high. For the fern watershed, for example, even in this short period of study, yearly runoff has averaged from as little as 0.3 inches to as much as 3.0 inches per year. Such small watersheds are obviously unreliable suppliers of water under present vegetation conditions and management.

Paul Duffy and
Teruo Yamamoto

Soil Erodibility Study

We have discontinued the use of Middleton's dispersion ratio because Hawaiian soils do not disperse easily and results of mechanical analysis are not reliable.

Researchers in the Agricultural Research Service recently reported that the number of small aggregates in a soil may be a better clue than soil texture in determining the susceptibility of soil to erosion. We have replaced the dispersion ratio with van Bavel's mean weight diameter of soil aggregates as the index of soil erodibility. The mean weight diameter is obtained by using the wet sieving technique of Yoder with modifications. Since Hawaiian soils are primarily latosols and its characteristics change by rainfall, which increases with proximity to the mountain summit, soils are sampled under varying isohyetal and vegetal conditions. Soil sampling on the Waianae Range showed volcanic ash soils more common than on the Koolau Range, previously sampled.

Teruo Yamamoto

Physical Characteristics of Some Hawaiian Soils

Further analysis of the soil trafficability data reveals that total pore volume of the upper 1 foot of soil for four different land use or vegetation types studied are nearly the same but pore size distribution differs. Total potential water storage capacity--sum of detained water (large pore volume) and available water volume--was calculated for each type. Forest soils were found to have the greatest potential total storage--13 percent more than pasture, 12 percent more than cultivated, and 10 percent more than idle grassland soils.

A summary of the information for the surface foot of soil follows:

Land use	Bulk density	Total pore volume	Large pore volume	Potential water storage
		Percent	Percent	Inches
Forest	.76	74	18	5.5
Pasture	.81	71	14	4.0
Cultivated	.88	69	10	4.1
Idle Grassland	.93	68	10	4.3

Teruo Yamamoto and Paul Duffy

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SEMIANNUAL REPORT

Division of Watershed Management Research
Rocky Mountain Forest and Range Experiment Station

September 1962 - April 1963

GENERAL

Following is a list, by major projects, of new studies proposed for the coming year.

(1602) Project: Water yield improvement in the snowpack timber zone, and reduction of storm runoff and erosion from rangelands, in the central Rocky Mountains.

Project Leader: Marvin D. Hoover (Acting)

Proposed Studies:

1. The influence of size of bare opening on runoff and erosion.
2. Seasonal sap movement in Englemann spruce and lodgepole pine.
3. Investigation of a device for measuring forest wind turbulence.
4. Snow accumulation and snowmelt patterns in an aspen forest of northeastern New Mexico.
5. Seasonal and diurnal changes in the water content and water deficits of aspen leaves.
6. Rime ice studies on high elevation watersheds of northeastern New Mexico.

(1603) Project: Improvement of water yields and soil stabilization in the Big Horn and North Platte River Basins and the Black Hills.

Project Leaders: H. W. Berndt and H. K. Orr

Proposed Studies:

1. A study of the hydrology of mountain bogs.

(1604) Project: Watershed rehabilitation to control erosion and sedimentation in the Southwest.

Project Leader: Earl F. Aldon

Proposed Studies:

1. Sediment production and runoff as they affect hydraulic variables in ephemeral streams.

2. Determination of critical factors in soil piping.

3. The effect of alkali sacaton on changing surface soil structure to increase water storage and decrease soil movement.

(1605) Project: Management of riparian and wet sites to reduce uneconomic or wasteful water consumption.

Project Leader: J. S. Horton

Proposed Studies:

1. Mechanism of salt secretion in tamarisk.

2. Seed germination of riparian species.

3. Effect of submergence upon tamarisk growing on reservoir deltas

4. Measuring evapotranspiration of different species and associations under varying environmental conditions.

(1606) Project: Water yield improvement for major upland areas of the Little Colorado, Salt, Verde, and Gila River Basins.

Project Leaders: G. E. Glendening and L. R. Rich

Proposed Studies:

1. Relative leaf moisture of selected chaparral species in relation to water availability and period of growth.

2. Site productivity and soil stability on some selected chaparral watersheds.

3. Streamflow and sediment production in high elevation grassland areas--Seven Springs.

4. Effect of wet meadows on streamflow.

5. Effect of frost, snow accumulation and disposition, runoff, and soil moisture of pulpwood cutting.

6. Vegetation, soil and other site factor inventory on the Whitespar Experimental Watersheds.

7. Variation in annual tissue moisture of ponderosa pine, Englemann spruce, and aspen in White Mountains of Arizona.

8. Methods for measuring channel transport of sediment in the chaparral type.

FORT COLLINS

Fool Creek Studies

This watershed study has been nominally in progress for 23 years. However, the actual period of study is composed of 12 years of calibration or pre-treatment years (1943-1954) and 7 post-treatment years (1956-1962).

Routing covariance analyses of annual water yields have been made to evaluate the effect of timber cutting on Fool Creek beginning with the first post-treatment year, 1956. The most recent analysis revealed an average yearly increase of 2.9 area-inches or 170 acre-feet attributable to the timber harvest. Chance variation could have been 1.0 inch, making the

odds 20:1 that the true effect of the harvest lies between 1.9 and 3.9 inches. Table 1 summarizes the estimated increased water yields from Fool Creek for all post-treatment years. Figure 1 shows the variation of the 95 percent confidence band of estimated increased water yields from year to year.

The apparent overall effect of timber harvesting is shown in figure 2, in which comparisons are made between the average Fool Creek and East St. Louis Creek hydrographs derived from the pre-treatment and post-treatment years[1/]. It can be seen that the largest percentage of increased yield took place during the spring freshet. However, streamflow has also been somewhat higher during the summer and fall months. Figure 3 shows the average monthly distribution of the May-September increased water yields from Fool Creek. Figures 2 and 3 indicate that roughly two-thirds of the May-September increase took place prior to the time of peak of the average post-treatment hydrograph.

Sediment Studies at Fraser Experimental Forest

Records of yearly sediment production from streamflow have been kept at the Fraser Experimental Forest since 1952. Annual surveys of accumulated sediment have been made at three watersheds.

Fool Creek Watershed.--The sediment from Fool Creek is deposited in a debris basin just downstream from the gaging station. It was constructed in 1951, and has a capacity of 1/4 acre-foot. The first measurements of trapped sediment were made in 1952.

The records obtained to date are not useful for determining the effect of timber harvest and its accompanying road system on sediment yield, due to the lack of pre-treatment data[2/]. However, sediment yields from this watershed have been relatively small. Since the beginning of record, the average accumulation in the basin has been about 900 cubic feet per square mile per year.

Deadhorse and Lexen Creek Watersheds.--Deadhorse and Lexen drain 667 and 306 acres of mountainous subalpine timberland respectively. Both watersheds are presently in the calibration stage.

In Deadhorse Creek watershed, a stilling pond was constructed in conjunction with a 120° V-notch weir in 1955. The basin has a surface area of 408 square feet. A similar pond was established at the Lexen Creek stream gaging site in 1956. Its surface area is 200 square feet.

1/ East St. Louis Creek is the control watershed.

2/ In 1950 and 1951, 3.3 miles of main access road and 8.6 miles of spur roads were constructed. During the period 1954-1956, 278 acres of timber were clearcut from this 709 acre watershed on an alternate strip basis.

Table 1.--Summary of covariance analyses to determine the effect of timber harvesting on annual water yields from Fool Creek--estimated increased yields.

Year	Period of record	95 Percent confidence interval of estimated increased yield.
		Area-inches
1956	5/ 3-10/12	4.2 ± 2.4
1957	5/23- 9/30	3.9 ± 1.9
1958	5/ 8- 9/30	3.0 ± 1.5
1959	5/ 8- 9/30	3.2 ± 1.3
1960	4/23- 8/24	3.3 ± 1.1
1961	5/ 6- 9/30	3.1 ± 1.1
1962	4/19-10/11	2.9 ± 1.0

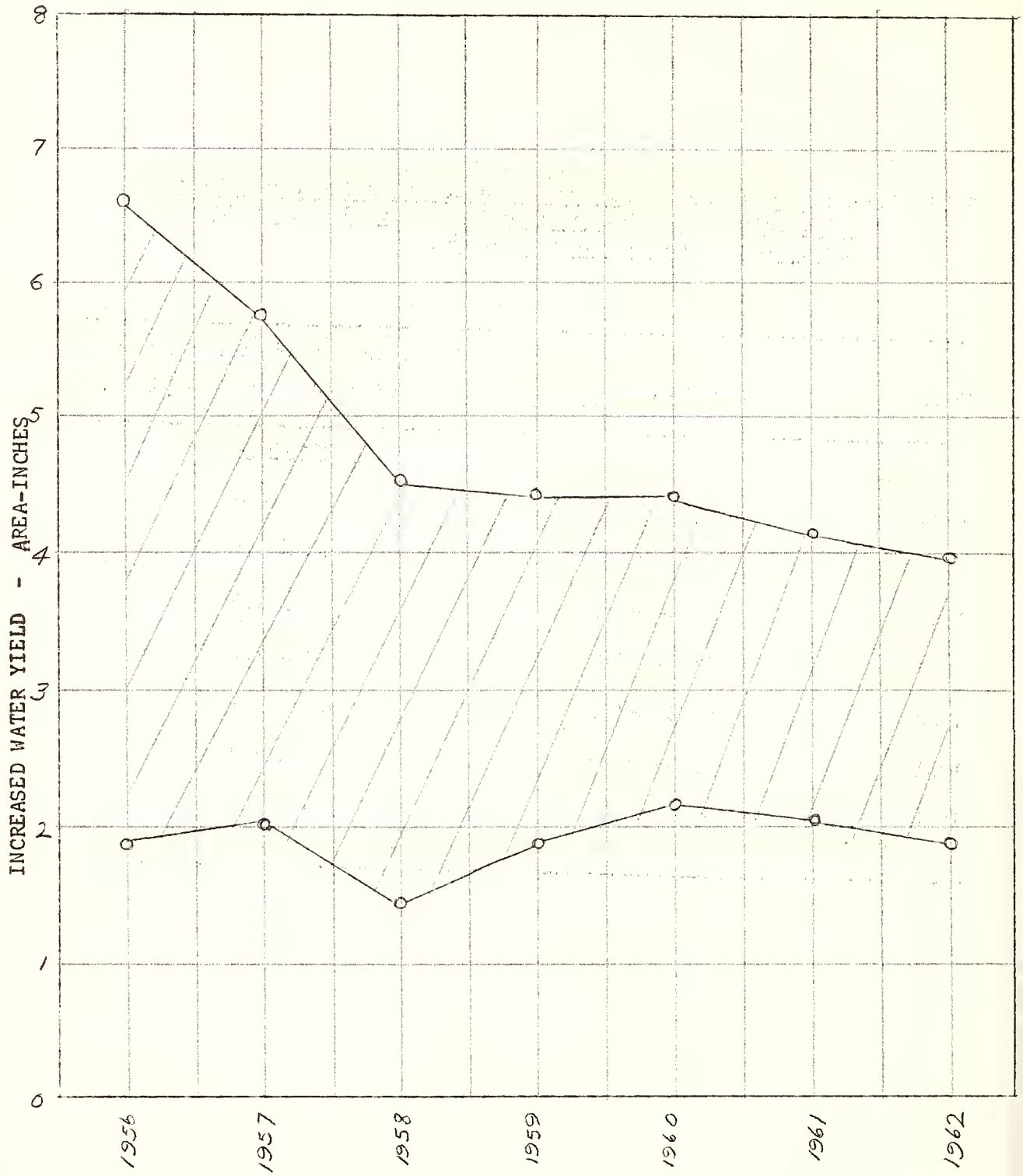


Figure 1.--95 percent confidence intervals of estimated annual increased water yield from Fool Creek watershed.

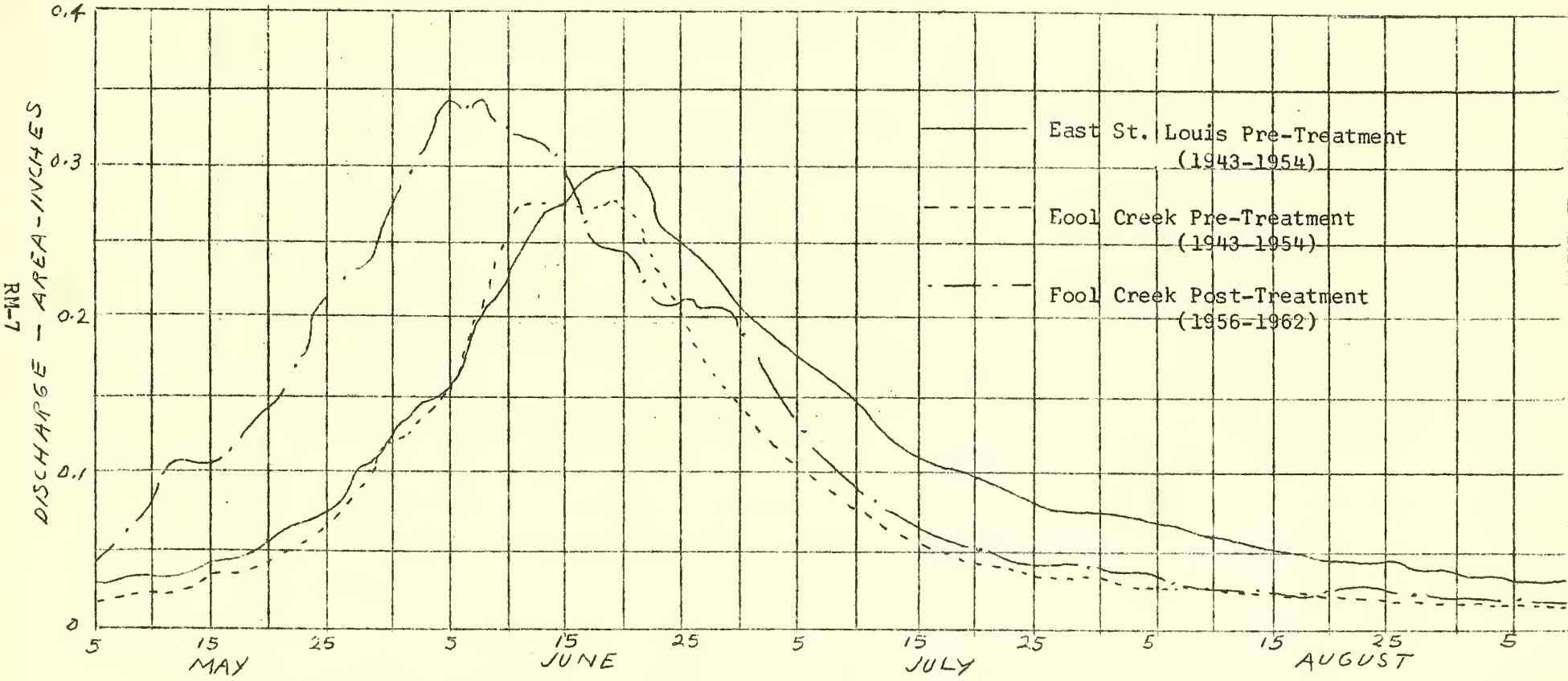


Figure 2.--Average hydrographs of Fool Creek and East St. Louis Creek

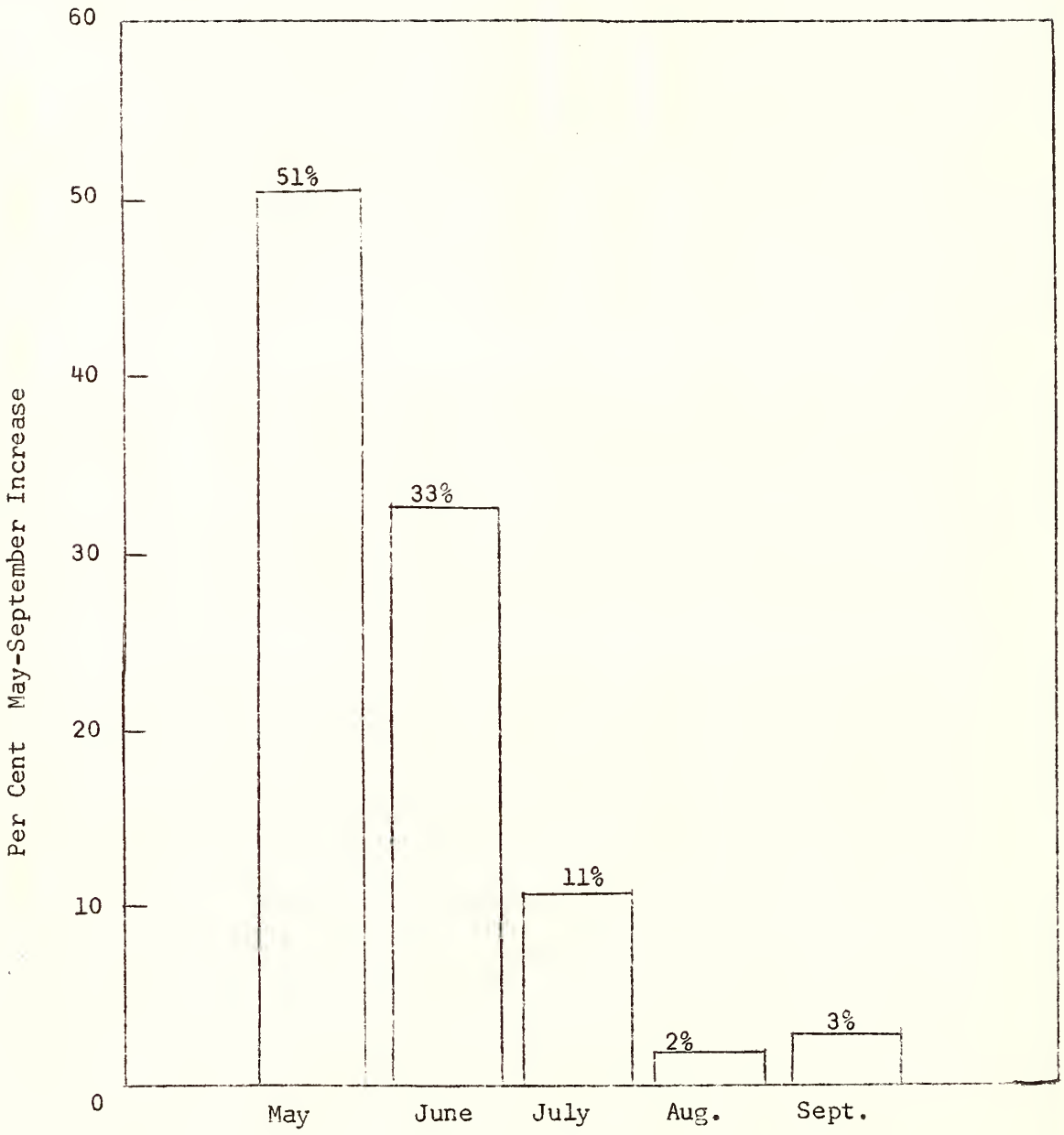


Figure 3.--Average monthly distribution of May-September increased water yield from Fool Creek.

Results.--Annual sediment yields in cubic feet per square mile and annual instantaneous peak discharges in cubic feet per second per square mile are summarized for each watershed in table 2. The yields are based upon gross volumes (sediment plus litter) as determined from yearly surveys of the debris basins.

Figure 4 shows the relationships between annual instantaneous peak and annual sediment discharge for the three watersheds. It is seen from these data that there is a high correlation between sediment production from the streams and peak discharge. This indicates that the major portion of sediment transported is composed of material which is derived from channel erosion and which moves as bedload. The apparently good correlation with peak discharge, in particular, has added significance since channel erosion occurs as a result of the forces exerted by concentrated flow.

It is suspected that the debris basins did not trap the total volume of sediment discharged from the watersheds. Probably a significant amount of the finer material passed through the basins in suspension, especially during high flow stages and after periods of rainfall. An estimate of the amount of gross erosion from the watersheds would require that the trap efficiencies of the debris basins be known. Moreover, such information is needed to evaluate the effects of proposed watershed treatment measures on total sediment yield in terms of channel and sheet erosion.

Additional Data Collection.--In addition to periodic surveys of the debris basins, we anticipate that suspended samples will be taken on a routine basis during the next runoff season. Also, a program has been initiated whereby samples of annually accumulated sediment are taken from the debris basins for laboratory analysis of such factors as particle size distribution, organic content, and dry density. The first samples were obtained last October, however, results are not yet available.

Charles F. Leaf.

RAPID CITY

Burned area stabilized within three years

Growth of herbaceous and native vegetation has runoff and soil erosion well under control within three years after the September 1959 Deadwood Fire. Total burn area was 4,500 acres. Most of the area was occupied by ponderosa pine of varying age and size, much of it dense.

Table 2.--Annual sediment yield and peak discharge from Fool, Deadhorse, and Lexen Creek watersheds

Year	Sediment discharge			Annual peak streamflow		
	Fool Creek	Deadhorse	Lexen	Fool Creek	Deadhorse	Lexen
	cu. ft./sq. mi.			c.s.m.		
1952	1498	---	---	21.7	---	---
1953	703	---	---	14.1	---	---
1954	----	---	---	2.2	---	---
1955	----	131	---	6.1	3.8	---
1956	1150	544	266	17.1	9.8	13.0
1957	2200	718	393	21.4	13.1	22.6
1958	1344	266	468	16.6	---	18.0
1959	270*	157*	83*	13.4	7.5	13.0
1960	436*	157*	80*	14.7	8.2	11.9
1961	192	32	13	7.8	3.7	6.7
1962	512	403	197	12.5	9.2	12.3

*Estimated--the basins were not surveyed in 1959

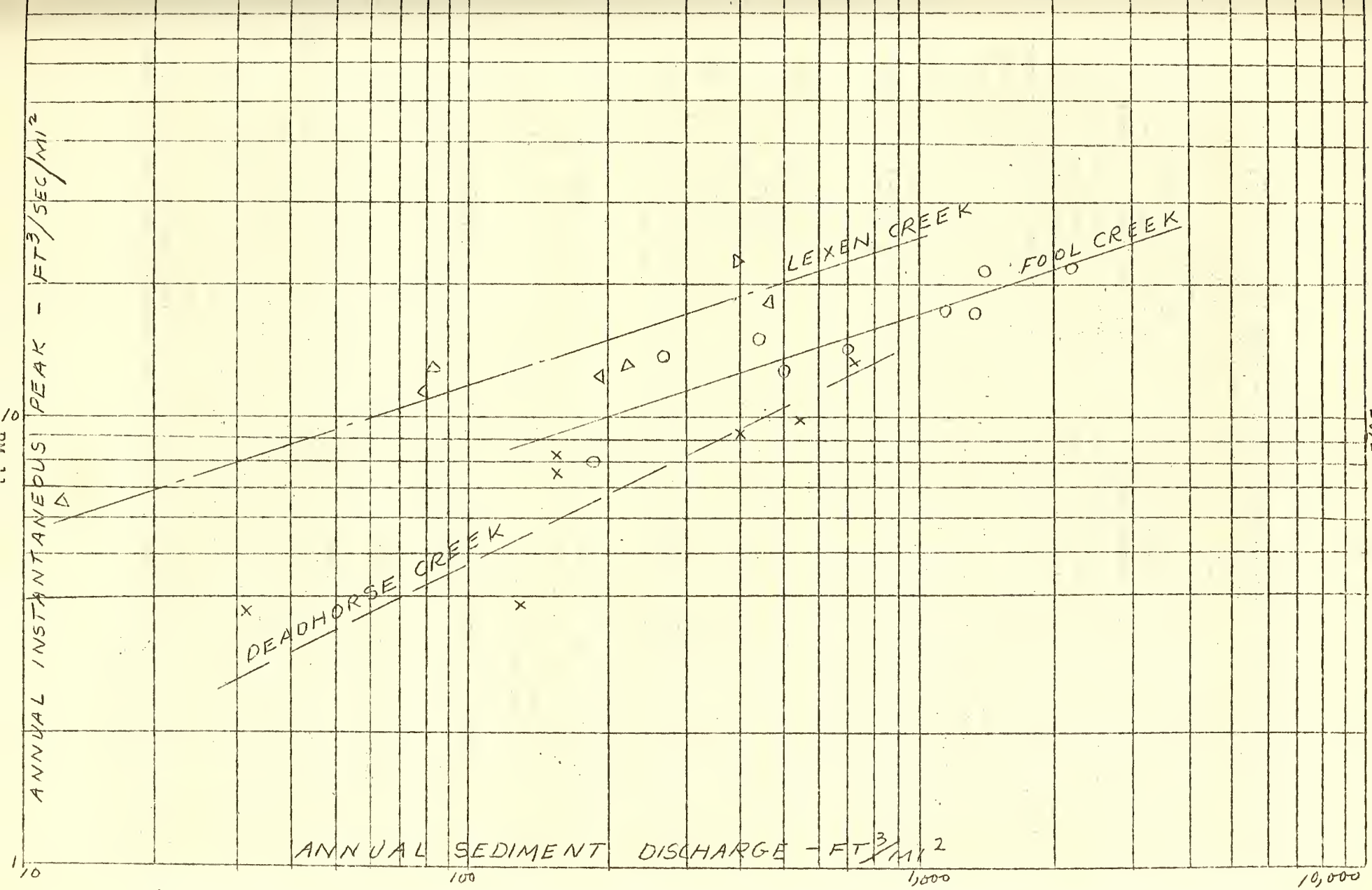


Figure 4.--Annual Peak Discharge vs. Annual Sediment Discharge from Streams in Fraser Experimental Forest.

The burn directly exposed Deadwood to a serious flood threat. An emergency rehabilitation program was organized and applied before the heavy spring precipitation of 1960. Forest Service land was contour trenched following salvage of as much as possible of the burned timber. On BLM land the burned timber was felled across slope and left in place. The entire area was then seeded by helicopter including all privately owned land, most of which received no other treatment. In the spring of 1960 a study was set up to evaluate control of runoff and soil erosion by the seeded and native vegetation. Eight 1-mil acre runoff plots were installed on each of two separate soil types. Within each group of eight plots four had relatively dense cover in 1960 and the other four had sparse cover. One site has a stoney loam soil while the other has a loam to clay soil. Four plots on the stoney loam site bare soil percentage dropped from 46 to 20 between 1960 and 1962. With this reduction in bare soil, summer storm runoff was reduced from 0.18 inch to 0.6 inch per inch of rainfall. On the clay loam site, bare soil dropped from an average 76 percent in 1960 to 35 percent in 1962. With this reduction in bare soil, runoff dropped from 0.23 inch to 0.06 inch per inch of rainfall.

On transects in each of the two major sites bare soil has been less each year than on the average plot. Percentages have been more nearly comparable to the dense cover plots. In 1962 runoff from the dense cover plots on the stoney loam soil averaged 0.14 inch for 28 inches total rainfall. This is more than three times greater rainfall than in either of the previous two summers. Average runoff from the dense cover plots on the clay loam site was 0.60 inch for 26 inches of rainfall. No more than these amounts of runoff would have been expected from plots on the transects.

Vegetation is as well established in the area where trees were felled across slope as in the area that was contour trenched. No destructive runoff came from the tree-felled area in 1962, or either of the previous two years.

Were contour trenches needed? Results suggest that here they were not.

New stream gage in operation

One of three stream gaging stations to be operated in a joint study by Research and Administration has been completed and is functioning. One objective of this study is to start getting inventory information of water supply. Another long range objective is to evaluate the effects of standard Forest Management practices in the Black Hills on water yield and quality. Initial treatment will involve application of standard practices on one watershed. Later a second watershed will be treated, the treatment designed specifically to increase water yield. These are the first watersheds gaged or to be gaged by the Forest Service in the Black Hills.

The first station was placed in operation last fall. Operation through the winter reveals some problems that will have to be solved in measurement of winter runoff. A thermostat controlled LP gas heater has worked nicely to keep the stilling well from freezing. But on several occasions the weir has frozen over. Any suggestions how this can be prevented will be welcomed.

Completion of the other two San Dimas flume 120° V-notch weir tandem setups is planned for this coming summer. During this time a slot diversion flow and sediment sampler will be tested at the Station already completed.

Howard K. Orr

LARAMIE

New facilities

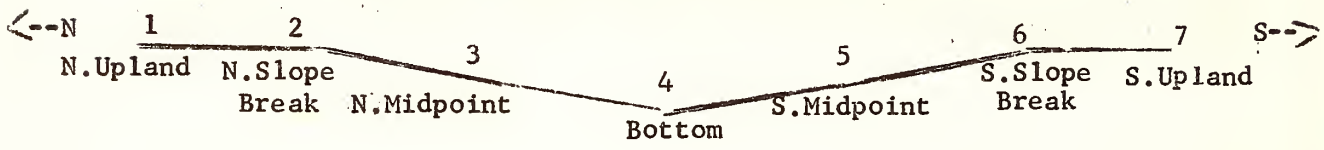
New Year's found us ensconced in our recently completed laboratory and office building near the eastern limits of the University of Wyoming campus. Some of the outstanding features of our new surroundings are: individual project leader offices, staff office for individual research functions, garage, greenhouse, and about 1,000 square feet of general soils, soil physics, and plant and soils chemistry lab space.

Snow fence spacing

Since late 1960 snow fence spacing trials have been made near Laramie on high windswept plains lacking sufficient barriers for natural snow accumulation. These trials are preliminary to a watershed study of the influence of snow fencing on streamflow. (Snow fence material being used in the tests is standard 4 foot slotted snow fence erected 6 inches above the ground.) Briefly, results have shown that a spacing interval of 325 feet is an effective placement pattern on upland areas. When so placed, each snow fence will induce a drift which extends about 110 feet downwind, has maximum depth of 54 inches (total barrier height), and contains about 108 cubic feet of water equivalent per lineal foot of snow fence.

The study area is predominantly rolling grassland with rather sparse eastward drainage. Channels are seldom deeply incised. Occasional experiences with snow fence constructed within or near channels have indicated that snowdrifting concentrates within these channels. As the channels provide excellent storage for snow, a snow fence treatment, probably different than that used on the uplands, should be developed.

This winter is being spent on studies of snow transport along representative downwind channels. Relative rates of snow movement past points in channel bottoms, as well as slope midpoints, slope breaks and uplands on both sides of the channel, are being sampled with snow-drift meters (the particular meter being used was developed by M. Martinelli, Jr. for use on alpine snowfields). Prior to a drifting event, seven meters are installed across a channel section with the following distribution:



Each meter is positioned with the horizontal orifice oriented upstream one foot above the ground. During a "run" all meters are exposed to drifting snow at the same time. The catch of each meter is related to the catch of the upland meters.

With our return to normal winter climate we have had several sampling opportunities since mid-January. Greatly condensed data from five runs show that up to 19 times more snow moves down a channel than moves past a point on the uplands. Hopefully, enough basic information should be gathered between now and spring to enable us to set up snow fence spacing trials in channels by next winter.

H. W. Berndt

Snow accumulation in big sagebrush

A study to determine the influence of big sagebrush upon snow accumulation was started this winter. Snow water equivalents are compared on similar sagebrush and grass covered plots. Observations of snowpack characteristics in both cover types are also being made.

A basic problem faced in this study is that of measuring snow accumulation in sagebrush covered plots where the aerial portions of the sagebrush plants are intermixed with snow. A three foot square cylindrical sampler is pressed down through the snowpack and the snow contained is removed and weighed. The total weight of snow contained in the sampler is converted to inches water equivalent. Results are being compared with results from Mt. Rose Snow Tube measurements. Ideas or suggestions pertaining to methods of measuring snow in sagebrush or other brushy cover would be appreciated.

Data collected thus far indicate that sagebrush areas accumulate significantly more snow than comparable grass covered areas. No differences in snowpack characteristics between cover types have been observed.

Future measurements will indicate whether or not these trends continue after sagebrush crowns are completely covered by snow. Also, the influence of big sagebrush upon the ablation of the snow cover will be followed.

B. A. Hutchison

Hydrology of mountain bogs

During the coming summer we plan to initiate the first in a series of studies of the hydrology of mountain bogs. Of primary interest will be studies of ground water behavior. The ultimate goal of this work is to determine if the water stored within a mountain bog is subject to water level control.

Late last summer a reconnaissance was made of bogs in the Medicine Bow Mountains of southeastern Wyoming. These observations have provided us with some background information vital to planning studies in these wetland types.

Apparently precipitation excess alone in the Rocky Mountain region is not great enough to allow bog formation. A supplemental source of water is necessary, and it usually comes from springs located within the bog or near the periphery. Also, bog formation is not dependent upon flat valley floors. Some were found on side-hill slopes of 10-15 percent. The bogs observed ranged up to 50 acres in size, but most fall within the 5-10 acre class. The fill was generally less than 8 feet deep and appeared to be entirely organic material (peat) underlain by a thin gleyed layer.

Plant communities found on the bogs ranged from Carex-Deschampsia (comparable to a wet meadow) through almost pure stands of willow (Salix spp.) to practically pure stands of spikesedge (Eleocharis) developing on the wettest sites high within a drainage. The bog selected for this first study is a 5-acre bog of this very wet spikesedge type.

D. L. Sturges

Beaver Creek Sediment Studies

A prototype sediment installation was constructed on a 1,150 acre ponderosa pine watershed during the winter of 1961-1962. It consisted of a sediment basin, spillway, and a series of three splitters for separating off a constant proportion of the flow. The splitters were designed so that the final split was 1/42,000 of the flow passing over the spillway. Redesign of some of the splitter components during spring runoff was made to eliminate catching of debris which obstructed the flow. The final setup consisted of a horizontal slot sampler for the first split, a single slot on an inclined ramp for the second split, and a multi-slot splitter for the final split.

Total runoff for the season was 812 acre-feet. The resulting sediment collected in the basin weighed 638 pounds, of which 80 percent was organic material and 20 percent inorganic. Maximum suspended sediment concentration recorded was 55 p.p.m.; the average was about, 10 p.p.m. An assumed average of 10 p.p.m. during the runoff season would mean that more than 10 tons of suspended sediment had passed over the spillway. Regardless what the actual average concentration was, suspended sediment accounted for the major portion of sediment movement in this instance.

On the basis of the results from the prototype sediment installation, two more installations were built in the fall of 1962. One is in Utah juniper type and one in pine. They are now (pending runoff) in the process of being calibrated.

Suspended sediment samples taken from 1958-1962 have pointed up several trends. (1) Sediment concentration is highest in the Utah juniper and lowest in the pine, with concentrations from Alligator juniper occurring in the middle (see figure 1). (2) There is a definite discharge-concentration relation, (see figure 1). (3) Summer concentrations are generally greater than winter and spring concentrations. (4) There appears to be a decreasing sediment concentration trend over the period of spring runoff. Future samples will be taken with the objective of clarifying these preliminary findings and eventually establishing a prediction equation for suspended sediment.

Ed Hansen

Recession flows from small watersheds at Beaver Creek

Average or "master" recession curves have been plotted for summer runoff and winter-spring runoff on eight Beaver Creek watersheds. These

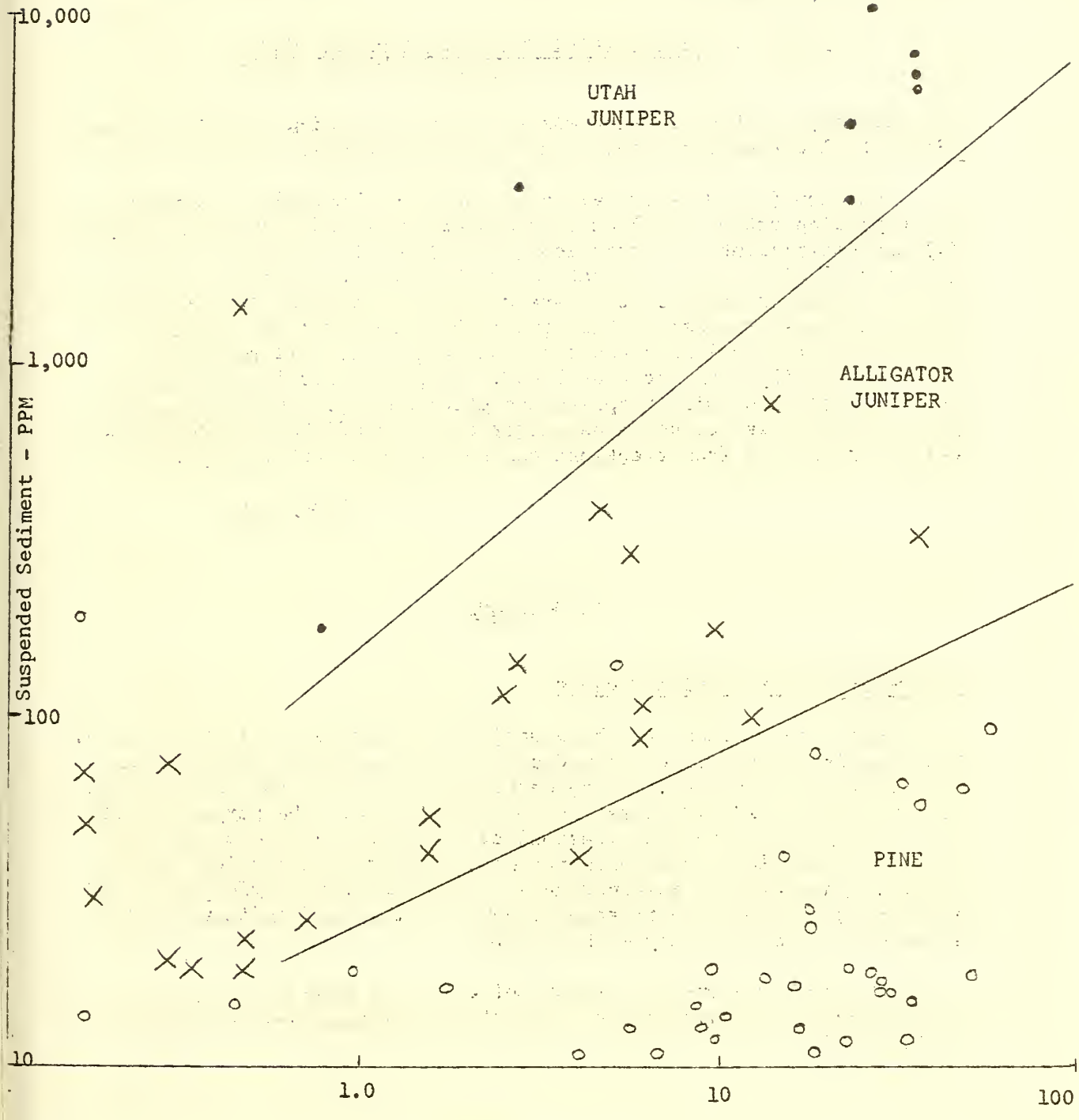

10,000
1,000
100
10
Suspended Sediment - PPM
UTAH
JUNIPER
ALLIGATOR
JUNIPER
PINE
1.0
10
100
Discharge - CFS

Fig. 1

curves, shown in the accompanying figure, represent the expected flow following the highest peak discharge on record, assuming no new precipitation. The slope of the master curve is an average of the slopes of all qualified individual recessions. Individual recession slopes are computed by

$$\text{slope} = \frac{\text{log initial CSM - log terminal CSM}}{\text{time}}$$

The validity of this equation was tested by comparing computed curves with actual curves for a large number of recessions.

Recession flow data are given in the following table. Included are depletion ratios (DR) of each master curve and standard deviations (s) and coefficients of variation (C of V) of the depletion ratios (these depletion ratios are ratios of the flow at any instant to the flow a half-hour earlier; they are a power function of the slope). The Pine Forest recessions have two limbs, the lower one being characteristically less steep than the upper one. All recessions were arbitrarily terminated at 1 CSM. Of particular interest is the low variability of winter-spring depletion ratios. The implication here is that this recession parameter can be predicted accurately and changes resulting from treatment can be detected statistically.

Harry Brown

ALBUQUERQUE

Watershed Rehabilitation Project

Runoff and sediment has been analyzed for the San Luis Study Area. The area is located in the semidesert type of central New Mexico on the Rio Puerco drainage. Three watersheds 364, 525, and 529 acres in size were set aside 10 years ago for calibration. The purpose of the study was to determine the feasibility of restoring through grazing management and land treatments the more deteriorated portions of this region. In addition, information is sought as to the effect soil and vegetation conservation treatments have on water and sediment yields. It is a cooperative study with the BLM.

Much of the vegetation aspects of the study have been reported on these pages in past issues. Runoff and sediment data were collected by the G. S.

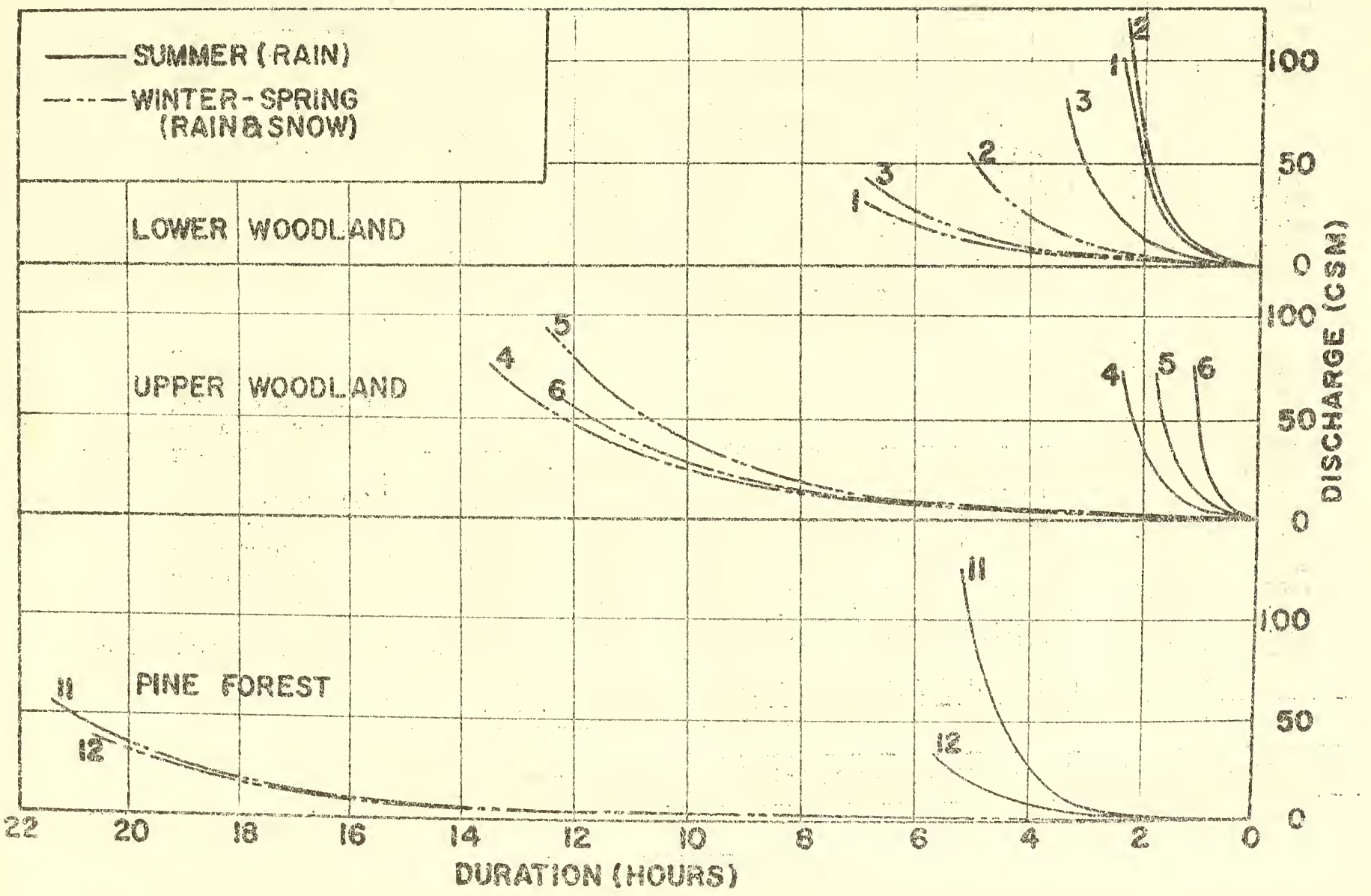

SUMMER (RAIN)
WINTER - SPRING (RAIN & SNOW)
LOWER WOODLAND
UPPER WOODLAND
PINE FOREST
1
2
3
4
5
6
11
12
100
50
0
DISCHARGE (CSM)
22
20
18
16
14
12
10
8
6
4
2
0
DURATION (HOURS)

Table 2.--Characteristics of master curves for simple recessions

		Lower Woodland Watersheds			Upper Woodland Watersheds			Pine Forest Watersheds	
		1	2	3	4	5	6	11	12
		Winter and spring recessions (mixed rain and snow)							
Upper limb	Initial CSM	30.340	55.380	42.540	75.180	93.050	58.150	54.890	37.920
	Duration (Hrs.)	6.860	5.110	6.900	13.500	12.460	12.170	21.400	20.640
	No. of recessions	8.000	8.000	9.000	14.000	5.000	4.000	5.000	4.000
	Average slope	.216	.341	.236	.139	.158	.145	.138	.124
	Average D.R.	.781	.678	.764	.854	.836	.848	.853	.868
	s of D.R.	.044	.063	.060	.043	.062	.057	.023	.046
	C of V of D.R.(%)	5.600	9.300	7.900	5.000	7.400	6.700	2.600	5.300
Lower limb	Initial CSM	---------- Does not apply ----------						4.900	4.380
	Duration (Hrs.)	" " "						13.800	13.080
	No. of recessions	" " "						2.000	2.000
	Average slope	" " "						.050	.049
	Average D.R.	" " "						.944	.946
		Summer recessions (rain)							
Upper limb	Initial CSM	101.880	120.060	80.110	73.400	72.750	77.020	125.250	33.250
	Duration (Hrs.)	2.400	2.350	3.400	2.400	1.800	1.170	5.190	5.670
	No. of recessions	5.000	6.000	4.000	7.000	7.000	5.000	8.000	2.000
	Average slope	.836	.886	.560	.776	1.033	1.608	.566	.328
	Average D.R.	.416	.414	.548	.480	.328	.172	.537	.686
	s of D.R.	.172	.218	.181	.237	.126	.081	.138	---
	C of V of D.R.(%)	41.300	52.700	33.000	49.300	38.400	47.100	25.700	---
Lower limb	Initial CSM	---------- Does not apply ----------						2.540	4.520
	Duration (Hrs.)	" " "						2.200	3.030
	No. of recessions	" " "						6.000	2.000
	Average slope	" " "						.184	.216
	Average D.R	" " "						.814	.783

Sediment production as measured in reservoirs ranged from 0.58 to 0.76 acre-feet per square mile per year for the 10-year period. Runoff ranged from 28.10 to 39.30 acre-feet per square mile per year (April 1 to November 1). Most of this plus the vegetative data is in manuscript form and in the review process. We are now further testing the data for ability to measure changes due to treatment.

Earl F. Aldon

TEMPE

Changes in water and sediment yields at Three-Bar Experimental Watersheds

An apparent change in water yield relations has occurred on two chaparral watersheds in the Three-Bar Experimental Area. This is believed to be related to the cumulative effects of three consecutive annual applications of 2,4,5-T on one drainage (Watershed C) following burning of all the watersheds in June 1959.

Five months after the third herbicide application, shrub crown canopy was 6.7 percent on Watershed C as compared to 27.4 percent on its unsprayed control, Watershed D. Average crown height was about two-thirds that on the unsprayed watershed, and there was about 50 percent defoliation of shrub live oak on the sprayed watershed.

Despite the massive cover removal caused by the fire, double mass plotting and regression analyses showed no change in the relation of streamflow on C to that on D from time of installation in 1956 through fall 1961, six months after the second spray treatment. Beginning in December 1961, and continuing every month through February 1963, the unit water yield on sprayed C has exceeded that on its control D.

Sediment yields, which were measured in thousands of tons per square mile during the first two years after the fire, have declined markedly. A recent 44-hour storm yielding up to more than 7 inches of precipitation, produced sediment as follows:

Watershed	Area (Acres)	Precipitation* (Inches)	Peak flow (Cu. ft.)	Sediment (Cu. ft.)
B	56	4.68	0.000	0
C	76	5.73	4.437	26
D	50	7.20	2.735	46

*Measured at the weir dams

The low sediment yields are believed to reflect increased infiltration capacity of soils on the slopes and improved stability of material in the drainage channels.

Through the cooperative efforts of the four agencies involved, an additional drainage was gaged at Three-Bar during the past month. All material for the small concrete block dam, stilling well, and V-notch weir were packed about one-half mile to the construction site by mules. This watershed, following calibration, will offer a chance for another treatment comparison.

George E. Glendening

Prescribed fall burning of chaparral

Second year results from prescribed strip-burning of chaparral have so far resulted in negligible soil movement except on very short, steep pitches. No sediment has moved into main drainage channels to date.

More extreme burning conditions in 1962 resulted in more complete destruction of shrub cover and litter than in 1961. The following tabulation indicates how removal of crowns and litter was related to climatic variables.

	1961	1962
Drought index	57	87
Rate-of-spread	5-10	10
Maximum air temperature	80	99
Shrub crown reduction (percent)	93	96
Litter reduction (percent)	28	51
Erosion	negligible	negligible

The strips to be burned were desiccated by spraying 2 lbs. per acre Dinoxol in oil about 4 weeks before burning. The 1961 burn was relatively cool, easy to control, and required continuous, almost shrub by shrub, ignition. In contrast, higher hazard conditions made the 1962 burn considerably more difficult to contain. In the 1962 burn the untreated brush would ignite readily, while in 1961 fire did not penetrate into the surrounding untreated cover.

Charles P. Pase

Vegetation sampling of a riparian community

We are developing a sampling technique which will determine species composition, density, and crown cover percent of vegetation in a riparian community between 1,500 and 6,000 feet elevation on Sycamore Creek in central Arizona. Aerial photographs with an average scale of 1:19,000 are being used to determine vegetation zones, vegetation communities, acreage of riparian vegetation, channel widths, and slope of channel walls. Large-scale photos will be necessary to identify species and determine their height and percent of cover.

A ground survey utilizing a count-list method of vegetation sampling has been started. Preliminary results indicate that the technique is satisfactory for our purposes.

Sycamore Creek will be divided into approximately 5-mile reaches for purposes of sampling. The number of acres of riparian vegetation per each 5-mile reach will be determined from aerial photos. Location of each sample plot will be random within vegetation types. Total number of sampling plots will depend upon number of acres and homogeneity of vegetation within the reach. Within each reach vegetation will be subdivided into the following zones: vegetation growing in stream channel; and, vegetation growing on terraces above stream channel on less than a 15 percent slope. Each sampling plot will consist of a circle with a 26-foot radius (0.05 acres). A 6-inch rangefinder will determine the limits of the circular plot. On each plot the number of trees, shrubs, and half-shrubs will be recorded by species. Diameter at breast height will be recorded on all trees. A canopy camera photo will be taken in the center of each plot. The canopy camera data will give an interesting comparison of crown cover to density figures determined from the circular plot measurements.

Since sampling of trees and shrubs will necessarily extend over seasonal periods, data on forbs and grasses will be sampled in a relatively short period on circular plots 89 inches (0.001 acre) in diameter. These data will be analyzed separately from the larger sampling plots. On the small plots we will record species and estimate total cover. The number of sampling plots of 0.05 and 0.001 acre sizes will be determined statistically.

Any suggestions which might improve our study will be greatly appreciated.

C. J. Campbell
J. S. Horton

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SEMIANNUAL REPORT

Division of Watershed Management Research
Southeastern Forest Experiment Station

October 1, 1962 - March 31, 1963

COWEETA HYDROLOGIC LABORATORY

Several waves of PWAP funds have rolled over us since October, totaling $152,000 to date. Coweeta at last is getting some much-needed sprucing up, chiefly construction, reconstruction, and repair of building, water lines, roads, trails, weirs and bridges. The following items may be of some interest.

1. The main office doubled in size.
2. A new 40 x 60-foot storage shed.
3. A new custodial dwelling.
4. A 40 x 100-foot meteorology-hydrology workshop, which we call the "Wet Lab."
5. A new 20,000 gallon water supply system.
6. All jeep and foot trails rebuilt.

In addition to these construction items, there are three new watershed experiments, totaling 500 acres.

Naturally, the work has had quite an impact, both favorable and unfavorable, on our research progress.

Microclimate Relations

Hamilton's extensive study and rain gages at San Dimas has led to a series of parallel studies at Coweeta which indicate that the problem is quite different in these high rainfall, heavily forested mountains. Here summer rains are relatively wind free, while February through April rains are not. Over the year, 20 percent of all rains are calm, 70 percent are accompanied by winds up to 4 miles per hour and 90 percent are accounted for by the combination of winds up to 5 miles per hour and all winds from the SW, S, and SE. Gages originally located in the forest but subsequently exposed by cutting show decreases, the greatest being 4-6 percent on south facing slopes. Winds decrease from ridgetop to base of slope, and also display two daily peaks (near noon and midnight), but without any consistent daily reversal such as those found in the Sierra Nevada. Comparison of tilted and vertical gages showed inconsistent differences of less

than 5 percent because the majority of our gages are shielded on the south by vegetation or land mass. At sites not so shielded, pit gages show an increase of 4 percent in summer and 12 percent in winter. Poor gage shielding is not the only cause of low gage catch on ridges. Along the east-west valley axis rainfall increases 10-15 percent per 1,000 feet rise in elevation until about 1,000 feet below main ridges. Here a dump zone of "blow over" rain occurs north of major gaps, increasing catch 7 percent per 100 feet elevation rise. But within the last 200 feet average catch decreases sharply (25 percent) to the ridge line. Therefore, careful selection of gage sites in relation to topography is emerging as more valuable in these mountains than construction of specialized tilted gages.

Plant-Water Relations

Continued study of the internal water balance of forest trees led to proposal of a regional Forest Drought Index (I) based on measurement of leaf-water deficit (WD) or the water potential of leaf water (DPD). Work with dogwood, a widespread understory species, suggested that I might be calculated

$$I = 2(6AM\ WD) + (2PM\ WD)$$

the index, varying numerically from 0 to 70, would be widely useful in forest research, because many physiological processes, including transpiration, are primarily controlled by plant-water stress. In an effort to develop this idea further, a simple chemical method (Schardakov dye method) for determining the DPD of leaf tissue was improved and tested as a field method for measuring water potential directly. So far it appears that leaf-water deficit is easiest to measure but a quick method for measuring water potential would be most desirable.

An improved method for measuring and estimating monthly litter interception was devised and an 18 month record indicates 1) that total annual litter interception in southern Appalachian hardwoods ranges from 2 to 4 inches and 2) that dormant season litter interception accounts for about 60 percent of the total. Thus at least one evaporative component seems greater in winter than in summer.

Soil-Water Relations

Evidence is accumulating to show that upland piedmont soils do not generally drain vertically beyond 6 to 10 feet in normal years of recharge. Instead water appears to move laterally below, and to a lesser extent, above the soil surface to the dissecting stream channels. These findings are causing us to reexamine our concepts of

the piedmont watershed to determine 1) which physiographic portions of the basin are supplying the 15 inches of annual flow measured there and 2) how upland soil water normally surplus to evapotranspiration is disposed of. Water management in the piedmont will hinge largely on answers to these questions.

Streamflow Relations

Annual water yield from a 22-acre watershed, converted from hardwoods to grass in 1959-1960, has not changed in three years of record. This was unexpected since most research has indicated that mature forest uses more water than low grass cover. We reserve conclusions pending a definitive test, in which all the grass will be killed with Dalapon to determine if any treatment will increase yield on this unit. In the meantime, Figure 1 shows the preliminary analysis of the forest-conversion-to-grass experiment. Known periods of leaks prevented use of all the calibration period data. The record shows significant increases during August-October each year except the last, but these are largely canceled by decreases during other periods. Although there is good information here, these data illustrate as well as any the difficulties we have interpreting results of nonreplicated watershed experiments.

Carding and computing of back streamflow, comprising 300 years of record, is 3/4 complete. Flow for periods of 1 day to 12 months are tabulated for 13 watersheds, as well as cumulative and non-cumulative flow frequency distributions for quarterly and annual periods. The first four moments (mean, variance, skewness, and kurtosis) of the FD curves relating percent of time to flow within classes have been computed for 2 watersheds and analyzed to determine if treatment effects might be demonstrated on factors other than total flow. The technique of multivariate analysis, in which FDs for different periods of record were treated as vectors, was used. The value of such an approach is based on the idea that the FD expresses more completely the behavior of a given watershed over time than any other single item except the hydrograph itself. We learned a good deal about multivariate analysis of streamflow, but must conclude that no "breakthroughs" have been opened up by the methods tested so far. However, the analysis of moments provided further and more elegant confirmation of the old fact that most paired watershed experiments lack sufficient length of calibration to demonstrate more than the grossest kind of treatment effect (for example, total flow and storm peaks for a specified rainfall). We do have fairly cheap statistical methods at hand to perform hypothesis tests on moment statistics of streamflow, but only the first moment (the mean) appears to have clear hydrologic meaning at present.

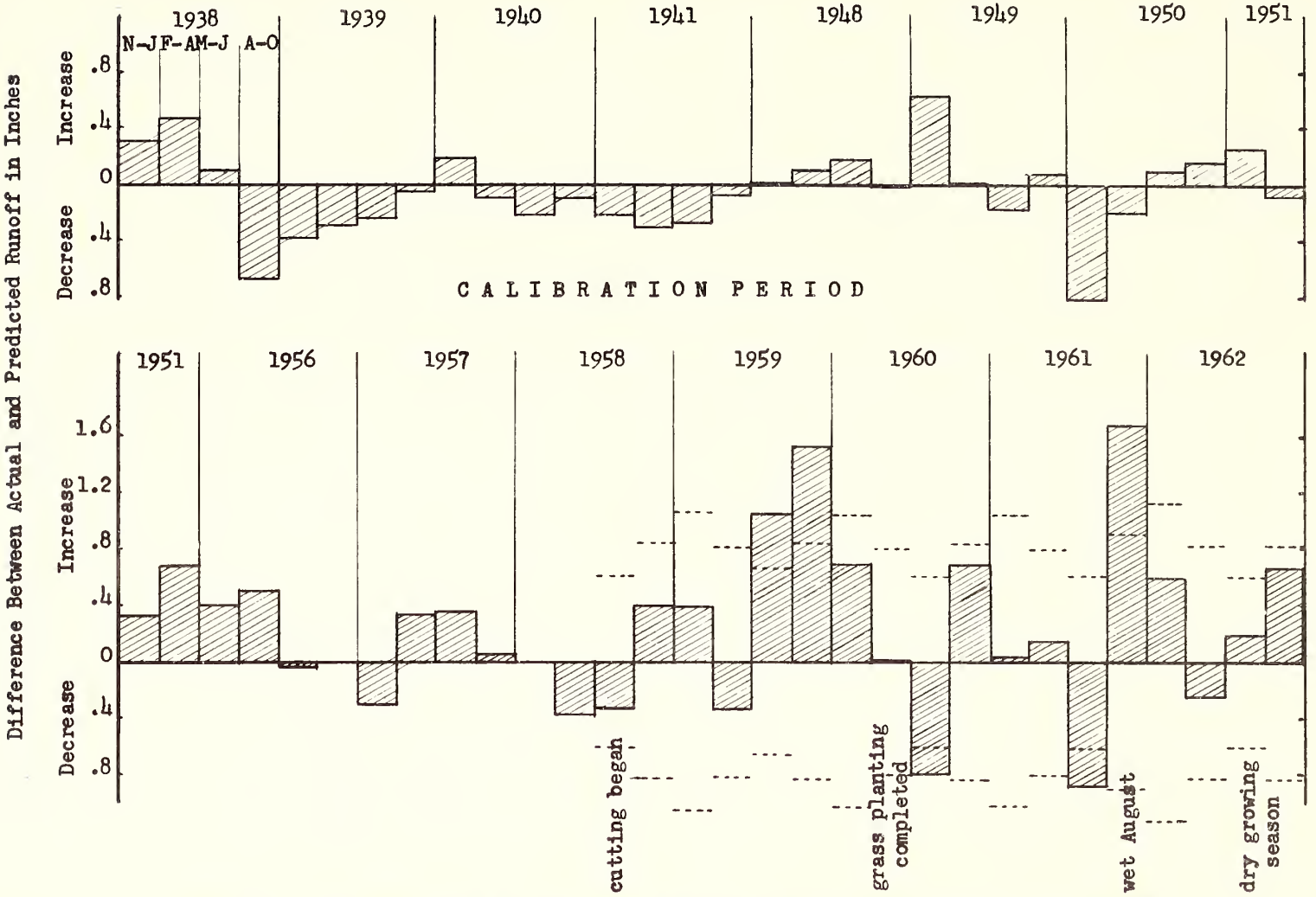

Figure 1. Differences between actual runoff (bars) and predicted runoff in inches for 3 month periods during calibration and treatment of Coweeta No. 6. Dashed lines indicate the .95 confidence interval.

Watershed #13, first cleared in 1940, had regrown a dense hardwood stand and water yield had returned close to pretreatment levels. Because of our troubles with unit watershed results, #13 was recut this year to determine whether the original increase in yield (16"/year reported by Kovner, Proceedings of Soc. Amer. Foresters, Memphis, Tenn., 1956) could be repeated. This becomes the first such experiment to be replicated in time; very fancy explanations will be needed if future records show no increases in yield. It takes courage to do this sort of thing!

Discussion

Most of us are in watershed management because water as well as timber is demanded of forest land. In addition, pressure mounts for hunting fishing, and recreational use of this land, even as the demand increases for water and timber. The principle of multiple use must truly set the course of all wild land management if we are to anticipate and adequately meet the needs of all forest users.

Multiple use as a policy is usually defined as a program for obtaining a variety of products and services from a group of forest resources. It is considered a desirable objective on the assumption that the sum of all an area's resource uses is of greater value than any single use. There are, of course, people who do not, or will not, recognize this objective. Controversy over ordering and integrating of uses tends to obscure the value of multiple use as a guide to public land management. Often this confusion stimulates single use interests to seek advantage while creating haphazard public opinion sometimes unfair and damaging to the multiple use concept.

At least part of the difficulty in visualizing multiple use stems from lack of concrete examples of land managed to provide several products and services. Using APW funds, we are setting up a 350-acre demonstration of multiple use management at Coweeta to provide a small working model of forest land as it might be managed in public or private use over the next 25 to 50 years. Particular attention has been given to the interests of municipal and industrial watershed managers whose problems focus most sharply on the water resource. It is our present thesis that water is the key resource against which to measure success or failure of any attempt to balance and regulate total use of these well-watered mountains. Not only should management units be based on watershed boundaries but practices designed to increase or to harvest any other resource would be evaluated in terms of effects on quantity and quality of the water supply. It is inconceivable that any practice damaging to the water supply can fail in the long run to damage the total productivity of the watershed.

Access is undoubtedly the key to multiple use management. After all, if you cannot get people in or products out, little management is possible. Barring logging and other access by helicopter, a comprehensive road network seems to be the only practicable answer. In the past, expediency of product removal has governed most forest road location, with consequences all toofamiliar to watershed managers. Adequately planned access requires consideration not only of existing forest resources but topography, road construction standards, and the foreseeable needs of the future as well. Our major concern was to reduce the preverse influence of topography on construction and especially on maintenance costs. To insure an adequate system, the following criteria were considered when planning roads into the demonstration:

1. Plan access into large units of land, for instance, a whole mountain ridge. We have used an already developed road for basic climbing access to the mountain ridge of which our demonstration is a part.

2. Plan access to serve all foreseeable forest uses and protection needs, costs to be amortized early as feasible in the timber cutting cycle.

3. Design the access system around a series of road and trail classifications which provide for maximum access at timber harvest but with minimum future maintenance.

4. Design for regulated road use by timber operators and the public, particularly during periods of heavy use and in adverse weather.

It is obvious that the several forest uses require varying degrees of access which logically follow a diminishing set of design classes Timber harvest always requires recutting periods of maximum access Between cutting cycles portions of the road system will not be needed and can be converted to wildlife plantings and trails. Furthermore, traffic load decreases and design criteria and maintenance may step down accordingly. This classification implies that climbing will be done on better classes of roads with access to work areas mainly from contour roads. Access of some sort is intended to serve every part of the demonstration. Less intensively managed areas will be accessible by foot trails only.

General

In accordance with the recent WO memo, we are beginning the practice of listing new studies by reproducing here a list of all Coweeta-Union studies now approved.

Title	Assignment
Microclimate	
The effect of mountain topography upon solar energy theoretically available for evapotranspiration.	Swift
A review of the relation of rain gage catch to actual precipitation on steep forested watersheds.	Swift
Addendum 1. Differences between standard and buried gage catches in exposed and sheltered forest openings.	Swift
Addendum 2. Wind speed and direction during rainfall on an exposed ridge.	Swift
Incident solar radiation on forested and cleared slopes.	Swift
Plant-Water Relations	
Internal water balance of forest trees as related to transpiration and drought.	Hewlett Patric Knipling
Addendum: Internal water balance as a forest drought indicator.	Hewlett
Distribution of roots of common forest trees in the Southern Appalachians.	Patric
Soil-Water Relations	
Movement and storage of soil water on steep slopes.	Hewlett
Addendum 2. Fluctuations in an artificial ground water table related to temperature and barometric pressure changes.	Hibbert
Addendum 3. Soil moisture drainage and storage patterns on a small mountain watershed.	Hewlett Helvey
Addendum 4. Moisture and energy conditions within a sloping soil model under natural rainfall.	Hibbert
Soil Model IV	Hewlett

Moisture storage and drainage of piedmont soil profiles.	Douglass
Addendum 1. Amount, rate, and duration of drainage in piedmont clay soil.	Douglass
Predicting soil moisture in steep terrain for hydrologic purposes.	Hewlett Douglass Helvey
Morphology of the soil mantle related to moisture storage and movement.	
Addendum 1. Use of a portable seismograph for determining depth of bedrock.	Douglass

Streamflow Relations

The effect of forest cutting on water yield.	Staff
The hydrology of mountain unit watersheds under several cover types	Staff
Mechanizing streamflow data collection and computation.	Hibbert Hewlett
A study of the high runoff-rainfall relation on Watersheds 36 and 37.	Hibbert
Source, volume, and timing of streamflow from mountain watersheds.	Hibbert
A study to improve hydrologic data computation and statistical analyses.	Staff
A regional study of the small watershed hydrograph based on records from Coweeta, Bent Creek, Union and Fernow	Hibbert Hewlett
A pilot application of the multiple use concept to a small mountain watershed.	Hewlett Patric Staff

Response to Drainage of a Wet Slash Pine Flat on the Apalachicola National Forest

In January 1962 slash pine was planted on a drained wetland pine site in west central Florida to observe the relationship between secondary drainage, water table levels, and early survival. Results after the first year indicate that the spacings tested had little relationship to water levels or tree survival.

The study is located in Franklin County, Florida on 0 to 2 percent slope, loamy fine sands underlain at 20 to 40 inches by sandy clay and clay subsoils. Prior to drainage soils remained saturated throughout most of the year. Consequently only a few scattered slash pine were able to become established on the site because of excessive soil moisture, and all of these trees displayed the unthriftiness typical of pine growing on poorly drained, coastal plain flatwoods. In 1961 primary drainage ditches, 4.5 feet deep, were dug by a dragline at ½-mile intervals. Excess surface water between the primary ditches was collected into 1.5 foot deep secondary ditches which ran perpendicular to the main drainage system at spacings of 330, 660, and 990 feet. Planned rate of water removal by the system was one-third inch in 24 hours. Nine months after completion of the ditching (Jan. 1962) slash pine seedlings were planted in small plots scattered between the collection ditches. In addition, a well was installed at each plot and readings recorded at two-week intervals.

Results of a recent field check showed slash pine survival was excellent on all plots, regardless of ditch spacing (table 1). Moreover, water levels averaged the same depth between each ditch spacing during the 1962 growing season. It remains to be seen whether the same relationships will hold in a wet year or whether even wider secondary ditch spacings can be used satisfactorily on such sites. In any event these preliminary results indicate an excellent, early response to drainage of sandy, flatwood sites that were once too wet to plant. The study and data analyses are still continuing.

Table 1.--Ditch spacing, average depth of the water table during the growing season, and first year survival of slash pine on a drained wetland site, 1962.

Secondary ditch spacing	Average depth to water table (Mar. - Oct.)	Average slash pine survival
Feet	Feet	Percent
330	2.67	96
660	2.67	97
990	2.67	96

Ralph A. Klawitter

Point Indexing of the Drainage State of Selected Drained Wetland Forest Areas

During the last 10-12 years thousands of acres of wet woodlands have been drained in the Southeast without adequate documentation of the change in soil, aeration, and moisture conditions of the areas. Furthermore, the proper drainage state for optimum tree growth is unknown at the present time and certainly different drainage levels are needed for each tree species grown. However, intensive study of the drainage state of an area requires measurements that are difficult and time consuming and methods are being sought to reduce the labor involved.

This study was installed during March on land owned by the West Virginia Pulp and Paper Company to provide answers on some of the problems raised in the preceding paragraph.

Specific objectives of this study are:

(1) Intensively define certain soil, hydrologic, aeration, and subsurface characteristics of index stations in selected drained wetland forests.

(2) Determine the soil, air, and water variables that most significantly influence tree growth at each index station.

(3) Determine the relationship between rainfall and (a) soil moisture, (b) soil porosity, (c) oxygen diffusion, (d) water table levels, and (e) oxygen content in surface and subsurface water or any combination of variables that seems reasonable or advisable at each index station.

Two 1/10-acre index stations with different soil conditions (one clay to 8 feet; the other sand to 9 + feet) were chosen for study. Loblolly pine trees 5-10 years old growing on the index stations will serve as phytometers for the soil, air, and water variables included in the study. Measurements of the variables replicated in time will be made every two weeks (table 1).

Table 1.--List of index station measurements, number of replications per index station and instrumentation used.

Type of Measurement	Number of Replications	Type of Instrumentation
Measurements Replicated in Time		
Rainfall	2	Standard 8" gage
Water table levels	5	1½" perforated steel pipe
Soil moisture	5	Troxler Neutron probe
Soil porosity	5	Data from soil moisture plus desorption curves
Oxygen diffusion	9	Sargent III Polarograph and platinum micro-electrodes
Oxygen concentration in surface and subsurface water	3	Sargent Oxygen Analyzer
pH of soil	5	Beckman pH Meter
Growth of loblolly pine trees	5	Growth bands and height
Measurements Not Replicated in Time		
Deep soil borings to 50 feet and soil texture	5	Minuteman Portable Drill
Earth resistivity measurements	2	Custom-made electrical resistivity apparatus
Desorption curves and bulk density	3	Lutz soil sampler and standard soils laboratory equipment
Hydraulic conductivity	3	Auger hole technique, equipment home made

This study will run for three years with provision for expansion of index stations as experience is gained on the best methods to define the hydrology of drained wetland forests and evaluate effects of drainage on tree growth.

Cortland E. Young, Jr.

SOUTHERN FOREST EXPERIMENT STATION
Watershed Management Research Semiannual Report

October 1962 - March 1963

General

Major effort at all projects has gone into completion of work on studies which are being terminated, and planning for work under the new program. Problem selections for all four projects and three problem analyses are in draft form. Work is under way on two additional problem analyses.

The Hydrology Project at Oxford is concentrating on analysis of runoff records of the 12 small watersheds in north Mississippi. Indications are that they will be able to apply cover treatments on six of them during the next year. At least one more year's calibration seems desirable for the others. Treatments will also be deferred on the three watersheds on Alum Creek Experimental Forest which are being calibrated by the Harrison Project. In both projects additional wells and access tubes for moisture measurements are being installed. Additional small watersheds are to be installed this spring near Oxford to study effects of timber management practices on runoff and erosion, and in Arkansas (Alum Creek and Koen Experimental Forests) to study water movement through sandstone-shale and cherty silt loam soils.

New Studies

FS-SO-1602-2.1	Effect of total crown area on the amount of throughfall in pole-sized loblolly pine plantations--Rogerson.
FS-SO-1604-1.1	The forest floor in loblolly pine plantations as related to stand and site characteristics--Williston.
FS-SO-1604-2.6	Effect of planting method, soil type, and sod density on the survival and growth of loblolly pine seedlings planted on road cuts--Williston.
FS-SO-1604-2.7	Effect of furrowing and scalping on loblolly seedling survival and growth--Williston.
FS-SO-1604-2.8	Effect of packaging method, storage method, and storage duration on loblolly pine seedling survival and growth--Williston.
FS-SO-1604-2.9	Seedling storage in refrigerator cars versus cold storage--Williston.

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McClurkin, D. C. Soil-site index predictions for white oak in north Mississippi and west Tennessee. March 1963. Forest Science.

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Ursic, S. J. 1963. Modifications of planting technique not recommended for loblolly on eroded soils. U. S. Forest Serv. Tree Planters' Notes 57, pp. 13-17, illus.

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Williston, H. L. 1962. Conifers for conversion planting in north Mississippi. U. S. Forest Serv. Tree Planters' Notes 54, pp. 5-7, illus.

_____, and MacNaughton, V. B. 1962. Timber management guide for Yazoo-Little Tallahatchie Flood Prevention Project. U. S. Forest Serv. and U. S. Soil Conserv. Serv., 42 pp., illus.

Submitted:

Ursic, S. J. Loblolly pine for erosion control in north Mississippi. (For Forest Service Research Papers Series).

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PINE LITTER ACCUMULATION

H. L. Williston

The primary purpose of planting millions of pine seedlings within the Yazoo-Little Tallahatchie Flood Prevention Project area in north Mississippi has been to produce a soil stabilizing mantle of pine litter. An informal assessment of litter accumulation in loblolly and shortleaf pine plantations with respect to stand density was made in the summer of 1962. Random samples were collected in 23-year-old loblolly thinned twice to 70 and 100 square feet and in 29-year-old shortleaf thinned twice to 70, 95, and 130 square feet.

Total litter in the loblolly plots averaged 6.24 tons per acre; in the shortleaf plots 3.94 tons per acre. This substantial difference in litter accumulation in favor of loblolly pine is an important factor in favoring loblolly for erosion control in this area rather than the native shortleaf.

Thinning treatment did not have a significant effect on either loblolly or shortleaf litter accumulation. Simple linear regressions were run to determine if the oven-dry weight of litter (exclusive of sticks) accumulated per acre on the study plots was directly related to litter depth. The equations developed were:

Loblolly litter in tons per acre = 2.83 + 3.21X where
X = litter depth in inches

Shortleaf litter in tons per acre = 2.80 + .58X where
X = litter depth in inches

There was a highly significant relationship between litter depth and tons per acre for loblolly but not for shortleaf.

It appears that within a relatively wide range of basal areas in stands under management we can expect to get much the same accumulation of litter for site protection. We suspect that this is because the greater crown volume per tree and larger needle size on heavily thinned plots compensates for the lower stand density and fewer trees per acre.